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PROBLEMS IN PERCEPTUAL DEVELOPMENT

A Thesis

submitted for the Degree of

Master of Education

in the

University of Durham

by

Gerald H. Fisher

1968

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ABSTRACT

The perceptual repertoire of human beings develops over a lengthy period of time. In maturity the spatial senses operate in such a way as to afford a veridical account of the physical environment. The reliability of sensori-motor behaviour and the accuracy with which spatial judgements can be made testify strongly to this. When required to process information of certain kinds, however, distortions are evidenced. Straight lines appear curved, regular forms are misshapen and forms of similar shape seem different. Thus, the spatial senses which allow reliable judgements to be made of some spatial patterns fail to do so when faced with others.

The most convincing theories proposed to account for distortions of this kind are based upon the assumption that experience of typical features of the spatial environment serves to modify perceptual organisation. An experimental and theoretical appraisal is made of the 'perspective' theory, the 'carpentered world' hypothesis and the 'size-constancy' theories in particular and the 'inappropriate size-depth' theories in general. The conclusion drawn is that these attempts to explain the development of perceptual organisation are unsuccessful.

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The perceptual repertoire of human beings develops over a lengthy period of time. In maturity the spatial senses operate in such a way as to afford a veridical account of the physical environment. The reliability of sensori-motor behaviour and the accuracy with which spatial judgements can be made testify strongly to this. When required to process information of certain kinds, however, distortions are evidenced. Straight lines appear curved, regular forms are misshapen and forms of similar shape seem different. Thus, the spatial senses which allow reliable judgements to be made of some spatial patterns fail to do so when faced with others.

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CHAPTER 1

INTRODUCTION:

THE DEVELOPMENT OF PERCEPTUAL ORGANISATION

The classical distinction between types of explanation of perceptual processes derived from the philosophical controversy over whether knowledge is obtained exclusively from the senses, or whether it can, in some way, be included in the native environment of living organisms. Locke, Berkeley and Hume developed the 'empiricistic' view implying that perceptual systems exhibit characteristic features of functional modification and change extending over relatively short periods of time. Kant was the principal exponent of 'idealism', proposing that living creatures are structured in such a way that some organisation of the perceptual systems is included in the native repertoire at the outset.

Philosophical controversy over behavioural and perceptual development has gradually been replaced by scientific investigation and debate. In the present century the nativistic idiom has been developed by Gestalt psychologists who dominated the field of perception during the

period intervening between the two World Wars. Their influence remains strongly felt, particularly in the field of perceptual development. Although it is seldom made explicit, Gestalt psychology was developed in its essentials from the work of Christian von Ehrenfels, the German philosopher, who proposed that certain features of perceptual organisation were 'invariant'. Thus, perceptual mechanisms operating in characteristic ways irrespective of culture and experience were understood to be 'givens' in the system. Today such a proposition would be expressed as involving mechanisms which are 'built-into' the genetic endowment of organisms. Empiricistic theories, on the other hand, have been developed in a variety of longitudinal, cross-sectional and cross-cultural studies. Important groups of research workers based in Geneva, under the leadership of Piaget, and in Clark University, supervised by Werner and Wapner, have engaged in long-term experiments of perceptual development. Here the developmental parameters of perceptual organisation have been submitted to detailed investigation, close attention having been paid to the early years of the human life cycle. The outcome of these studies is not entirely unequivocal. In general, however, they indicate that the organisation of the perceptual repertoire of human beings develops over a lengthy period of time, being incomplete until adolescence, and

subsequently, undergoing further modification beyond maturity.

The present investigations are concerned with features of the development of space perception. A good deal of the behaviour of human beings about the world involves them in making implicit judgements of the spatial information afforded by the presence of objects, structures and forms in the immediate environment. This information is encoded by the end-organ transducers incorporated within the spatial senses. Its correlates are analysed in the projection systems with which they ramify. The reliability of sensori-motor behaviour testifies to the facility with which the sensory and perceptual systems are usually capable of fulfilling their functions. This is such as to provide a remarkably accurate account of the spatial environment. When required to process information of some kinds, however, certain distortions become evident; straight lines appear to become appreciably curved, regular forms are grossly misshapen and identical shapes seem markedly different. Accordingly, the information-processing systems which function so as to allow highly reliable judgements to be made of the forms of some spatial patterns fail to do so when faced with others.

Many theories have been formulated in the attempt to account for the departures of the phenomenal attributes of spatial patterns from their physical characteris-

tics. The most persuasive and widely held of these are based upon the assumption that experience of typical features of the spatial environment serves to modify perceptual organisation. In the remainder of this work a detailed theoretical and experimental appraisal is made of what are considered to be the more important examples of theories of this kind. The arguments are developed throughout Chapters 2, 3, 4 and 5 in such a way that each chapter is intended to be complete in itself. While this makes for some repetition it obviates tedious cross-reference and thus preserves clarity.

CHAPTER 2

ILLUSIONS AND PERSPECTIVE

The appearances assumed by certain line-drawings are contrary to their physical forms. It is customary to refer to two-dimensional figures of this kind as 'geometrical illusions'. In the latter part of the nineteenth century experimental physicists, physiologists and psychologists became preoccupied with studying the distortions evidenced in illusions. Many explanations for their appearances being at variance with their denotable physical dimensions were proposed. The view held in favour for the longest period of time was first formulated by Armand Thiéry in 1896 and is still accepted widely. Thiéry drew attention to the resemblance of some illusions to two-dimensional drawings of real-life scenes and concrete objects. The most well-known and widely-studied illusion, for example, that described by Müller-Lyer in 1889, reminded Thiéry of the cross-member and trestle-legs of a saw-bench. The closeness of this resemblance led him to propose that familiarity of three-dimensional scenes and solid objects might be conducive to the appearance of distortions in certain two-dimensional line-drawings. Wood-

worth (1938) and others subsequently formalised Thiéry's argument in describing it as 'the perspective theory'.

The explanatory features of the perspective theory rest upon a simple and persuasive assumption. This is that the organisation of the perceptual mechanisms responsible for the appearance of illusions is initiated and developed specifically as a consequence of experience of features of three-dimensional space. Illusions become apparent in two-dimensional spatial patterns. Some of these resemble plan-, front- and side-elevation projections of three-dimensional objects and structures. In the visual world, the actual parts of such structures are located at different distances with respect to the eye of an Q. Accordingly, the retinal images due to them differ in size. In general, those parts which appear further away are smaller than others which seem to be relatively closer. Certain spatial scaling mechanisms are brought into operation when judging the sizes assumed by objects in relation to the distances at which they appear to be placed. The perspective theory implies that these same perceptual mechanisms operate when viewing two-dimensional patterns. But the characteristic functional modes of such mechanisms fail to be appropriate when they are required to extrapolate information from some of these patterns. When this is the case an illusion arises. By extension it may be argued that,

according to the perspective theory, illusory distortion of two-dimensional space is the price paid by the visual projection system for veridical perception of three-dimensional space.

The purpose of this chapter is to consider the validity of the argument for the relevance of perspective to illusions by submitting both its assumptions and implications to experimental consideration and to theoretical discussion.

EXPERIMENT 1

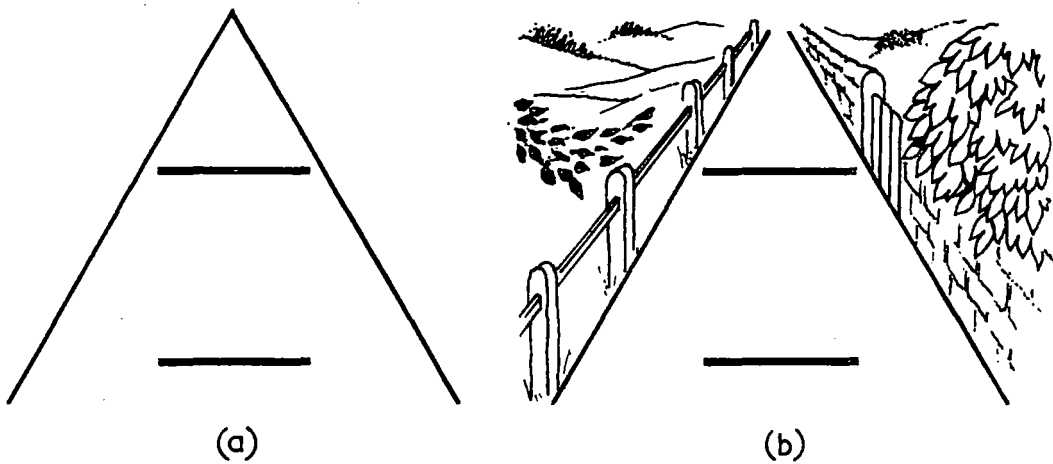


FIG. 2.1 THE PONZO ILLUSION AND A PERSPECTIVE DRAWING OF A THREE-DIMENSIONAL SCENE

The illusion to which the perspective theory is most obviously relevant is the one which arises in the figure described by Mario Ponzo in 1912. Known appropriately as the Ponzo illusion, this is a two-dimensional pattern defined by two horizontal lines enclosed within an inverted V-shaped bracket. Although the horizontal lines are identical, under the influence of the illusion, their lengths appear to be appreciably different. This illusion is illustrated in Fig. 2.1a, in which the upper horizontal seems to be somewhat longer than the lower. The Ponzo figure is strongly reminiscent of two-dimensional projections of road-ways, or railway-tracks, which have extension in the third dimension. Horizontal lines superimposed upon perspective drawings of familiar scenes undergo distortion similar to that evident in the Ponzo illusion, an example of such a distortion being illustrated in Fig. 2.1b. Here again the upper horizontal appears longer than the lower, notwithstanding the fact that the two lines are of exactly the same length.

To consider the influence of features indicative of depth, present in two-dimensional spatial patterns, five new versions of the Ponzo illusion have been prepared. Perspective treatments were introduced into each of these by representing the oblique components of the figure as projections of solid, square-section rods. These draw-

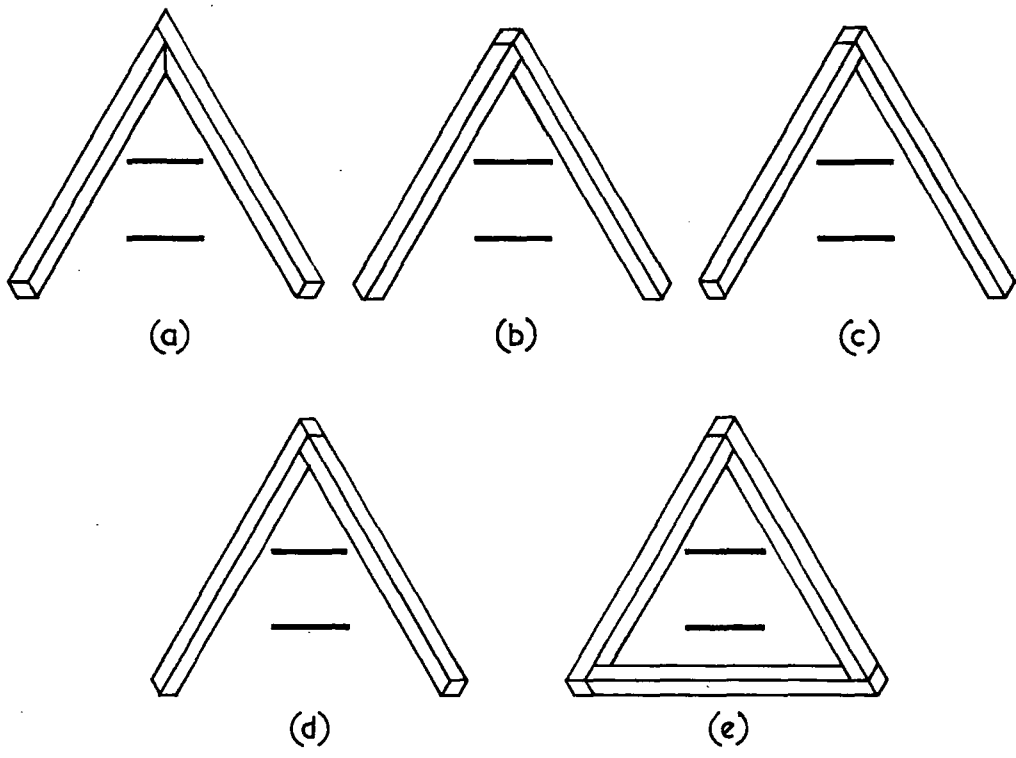


FIG. 2.2 VARIATIONS OF THE PONZO FIGURE CONTAINING A VARIETY OF PERSPECTIVE FIGURES

ings are illustrated in Fig. 2.2. Fig. 2.2a follows the conventional form of an angular pattern representing a typical scene, or structure, in three dimensions, increasing distance being indicated by convergence. The rods forming the oblique aspect of the figure are drawn in such a way as to appear to project backward into space toward the point at which they meet when a three-dimensional interpretation of its form is maintained. In

figure b the perspective conventions have been reversed and the point of intersection of the two rods appears to project forward so as to seem closer to Q than the open ends. One of the two rods in both figures c and d is drawn so as to appear to project forward, the other backward. The form illustrated in figure e is 'impossible' as drawn, since it contains contradictory information in the third dimension. Of the three intersections of the rods, any two are incompatible with the third. To this spatial paradox there can be no unique solution. Hence, no conceivable interpretation of the form of this pattern can possibly succeed in realising it as such a structure having extension in three-dimensional space.

Method and procedure

An apparatus was constructed using which two horizontal slots, seen as white bars against a black background, could be adjusted in length from 70 to 130mm., symmetrically about their centres. The slots were displaced by a vertical distance of 50mm., they were 5mm. wide and the background against which they appeared was 610mm. square. The oblique aspects of the five patterns

shown in Fig. 2.2 were painted in white line upon sheets of a transparent plastic material. These were placed in front of the background display through which the bars could be seen clearly. An appropriate control situation using a plain plastic sheet was introduced also. The six displays were presented in a randomly determined order to a sample of 100 individual Os. Their perspective features were pointed out to all Os who, whilst maintaining an appropriate depth interpretation of each form, were required to adjust the lower horizontal line so that it appeared to be of the same length as the upper, this being presented in a standard length of 100mm. Each O made ten judgements in relation to each display, initial lengths of the variable slot being randomised appropriately.

Results

The results of this experiment are shown in Table 2.1. Numerical values expressed in mm. indicating the extent to which the variable line was adjusted so as to appear of the same length as the standard are entered in relation to each background pattern used. Data were

TABLE 2.1

COMPARISON OF THE EXTENT OF THE PONZO ILLUSION IN SIX PATTERNS EMBODYING DIFFERENT PERSPECTIVE FEATURES

FIGURE	2.2(a)	2.2(b)	2.2(c)	2.2(d)	2.2(e)	CONTROL
\bar{X}	9.47	9.75	9.49	9.87	9.87	0.36
$\delta\bar{X}$	0.41	0.50	0.48	0.49	0.45	0.35

recorded as the length of the variable in excess of the standard to avoid unwieldy units of comparison. Beneath each mean value (\bar{X}) is entered the associated standard error of estimate ($\delta\bar{X}$). Comparison of the distortion seen in each oblique pattern with the control situation shows clearly that an illusion characteristic of that seen in the Ponzo figure becomes evident in each display pattern. But the magnitudes of the five distortions do not differ significantly. Accordingly, it is clear that the different perspective features of these patterns are not instrumental in inducing different degrees of distortion.

EXPERIMENT 2

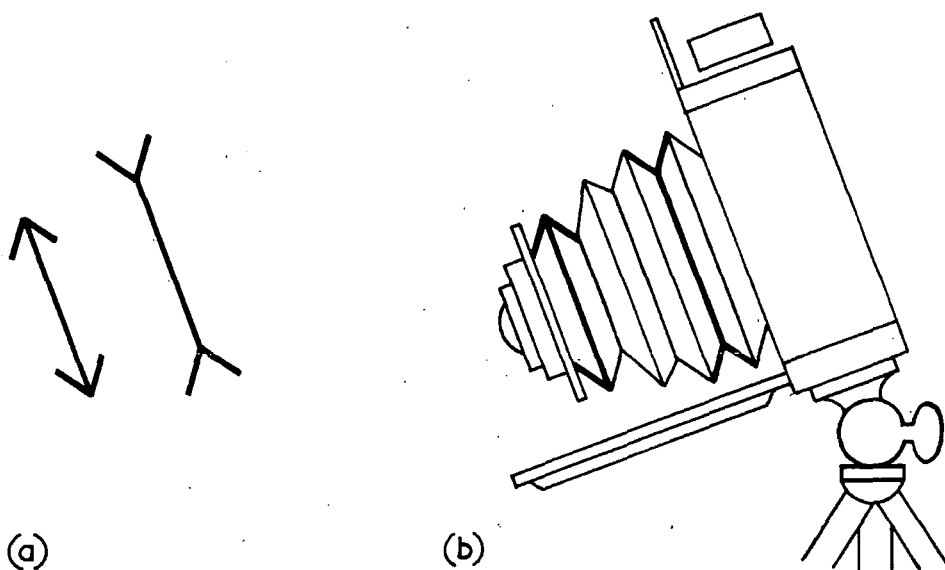


FIG. 2.3 THE MÜLLER-LYER ILLUSION AND A DRAWING OF A CAMERA WHICH CONTAINS THE FIGURE

Thiéry specifically drew attention to the similarity of the Müller-Lyer figure to a two-dimensional projection of a saw-horse. Consideration of Fig. 2.3a, however, reveals this similarity not to be so close as it might appear at first sight. If the conventions of perspective are observed, a two-dimensional projection of a straight beam fitted with trestle legs cannot be drawn in such a way as to resemble a pattern isomorphic with that of the composite Müller-Lyer figure. Two-dimensional drawings of other scenes and figures, however,

resemble the Müller-Lyer pattern more closely. One example of these is shown in Fig. 2.3**b**. Here the fold of the bellows of the camera bounded by outgoing brackets appears to be somewhat longer than that bounded by ingoing brackets. Nevertheless, the two folds are identical in length.

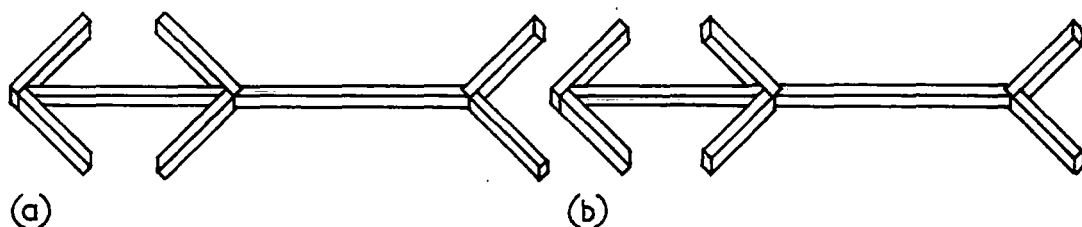


FIG. 2.4 MÜLLER-LYER FIGURES EMBODYING DIFFERENT DEPTH FEATURES

Müller-Lyer figures with strong depth features may be devised so that the possibility of any influences arising as a consequence of the perspective elements contained within them can be considered. Examples of such figures are illustrated in Fig. 2.4. Figures a and b show that the Müller-Lyer illusion represented in two conventional perspective forms. The difference between these should be noted. A number of theories have invoked the influence of perspective features embodied

in the Müller-Lyer and other illusion-figures upon the distortions apparent in them. Significant of these were those formulated by Tausch (1954), von Holst (1957) and Gregory (1963 and 1966a). Gregory, for example, observed that the part of the shaft bounded by outgoing arrow-heads is strongly reminiscent of a projection of the inside corner of a room while that bounded by ingoing arrows resembles the outside edge of a building. A partially acceptable 'explanation' of the distortions evident in these figures may be developed in these terms. But the distortion continues to arise in the conventional form of this figure, this being the composite version represented as a single shaft bracketed and bisected by arrow-heads. The implication of this is that each half of the shaft of the complete Müller-Lyer figure should be seen at a different apparent-depth simultaneously. Hence, the reference-plane set by the ends of the bisecting arrow-head must be seen as both nearer to, and further from, 0 at the same time if a consistent three-dimensional interpretation of the form of such a figure is to be maintained. It may be possible to attempt to extend previous arguments by claiming that the central arrow contains ambiguous depth features and that it appears to alternate in apparent-distance in such a way as to become associated first with one, then with the other part of the figure. As far as we are

aware, however, neither differences in apparent-depth of the two parts of the composite Müller-Lyer figure nor reversals in aspect of its component parts have been reported.

In both patterns illustrated in Fig. 2.4 the left-hand arrow-head is represented perspectively in such a way that the tip is apparently nearer in space than the ends, the reverse being the case for the right-hand arrow-head. In Fig. 2.4_a the bisecting arrow follows the perspective treatment of the left-hand, or ingoing, arrow-head, while in Fig. 2.4_b it is represented in the same way as the right-hand, or outgoing arrow-head. Using these figures the problem of the association of the central angular form with each of the pairs of obliques bounding the shaft of the figure may be considered independently. Further drawings introducing variations upon these perspective treatments were made also, these being shown in Fig. 2.5. One arm of each of the arrow-heads in these patterns is represented in such a way as to appear to project forward, the other backward.

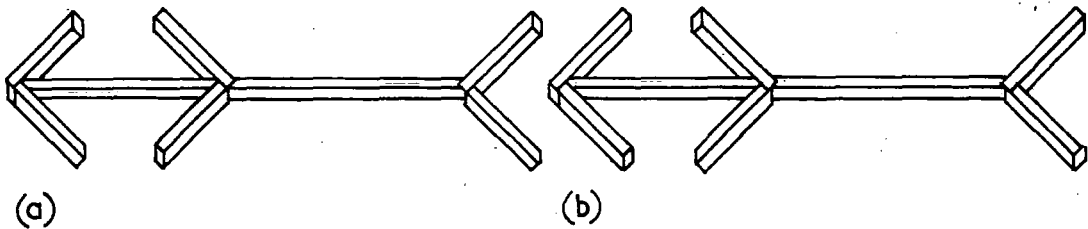


FIG. 2.5 FURTHER MÜLLER-LYER FIGURES WITH FURTHER DIFFERENT DEPTH FEATURES

Method and procedure

The shafts and the arrow-heads bounding all four patterns illustrated in Figs. 2.4 and 2.5 were drawn in black line upon the surfaces of sheets of dense white plastic. In each case the shaft was 100mm. and the bracketing arms 20mm. long. The arrows bisecting the four figures were drawn on sheets of transparent plastic. Fitted into channels bordering the longer edges of the white sheets, these arrows could be moved readily along the shafts of the figures which were seen clearly through the transparent material. Scales fitted to the rear faces of these 'slide rules' allowed the position of the slide with respect to the fixed aspect of each display

to be determined.

All four patterns, along with a conventional Müller-Lyer figure containing no defined depth features, other than any which may be embodied intrinsically within it, were shown individually in a randomly determined order to a sample of 100 Os who were required to place the sliders into such positions that the two parts of the shaft of each figure appeared to be equal in length. Os made four judgements in relation to all figures, initial positions of the sliders and left-right orientation of the two parts of each figure being randomised appropriately throughout.

Results

TABLE 2.11

COMPARISON OF THE EXTENT OF THE MÜLLER-LYER ILLUSION IN FIVE FIGURES EMBODYING DIFFERENT PERSPECTIVE FEATURES

FIGURE	2.4(a)	2.4(b)	2.5(a)	2.5(b)	CONTROL
\bar{X}	7.74	7.74	7.82	7.68	7.76
$\delta\bar{x}$	0.25	0.25	0.26	0.30	0.27

The results of this experiment are entered in Table 2.11, according to the convention used previously. They indicate the position to which each bisecting arrow-head was adjusted with respect to a datum referring to the position of actual bisection. Again, it is clearly evident that the five magnitudes of distortion do not differ significantly in a statistical sense. Accordingly, as before, the different perspective elements of these figures do not appear to introduce different degrees of illusory distortion.

EXPERIMENT 3

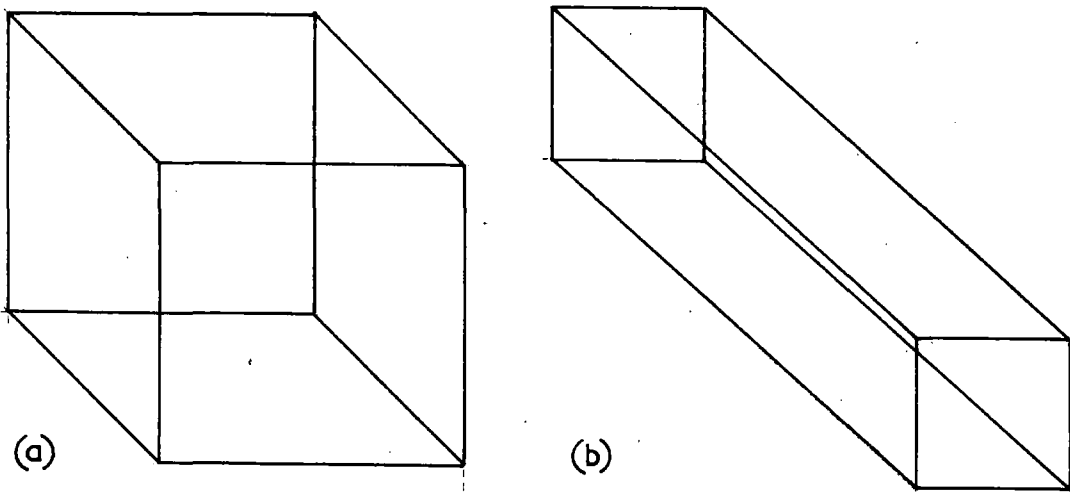


FIG. 2.6 THE NECKER CUBE AND AN ELONGATED SKELETON FIGURE

Some two-dimensional figures are strongly reminiscent of three-dimensional forms. Perceptually, such figures are paradoxical since, although they are manifestly flat, it is difficult to resist interpreting them as forms having extension in depth. Other figures are 'perceptually ambiguous' in the sense that they may be interpreted as the same form or structure seen from two different vantage points. It is not unusual for the lower square face of the Necker cube, illustrated in Fig. 2.6a, for example, to appear closer than the upper when the figure is first seen. After a few seconds of observation, however, the pattern changes in aspect, whereupon the component elements of the figure appear to undergo reorganisation in the third dimension. In one aspect of the Necker cube the lower square face, orthogonal with the line of regard, appears to be nearer than the upper; in the other, the upper face appears nearer than the lower. According to the perspective theory, since the two faces differ in apparent-distance, they should also differ in apparent-size.

There is some disagreement in the literature over whether, or not, size changes do, in fact become apparent depending upon the aspect in which the Necker cube is seen. Sanford (1894) insisted that they were capable of being seen clearly, while Gregory (1966b) reported inability to observe such changes when the figure

was presented within a clearly defined two-dimensional context. He noted further, however, that appropriate changes appeared when the cube was shown to Os in 'reduced-cue' conditions in such a way as to remove the influence of the two-dimensional surface upon which it was drawn. This evidence was critical to Gregory's development of a version of the theory which rejected the relevance of perspective and attempted to bring the notion of constancy to account in explaining illusory distortions. Gregory's grounds for rejecting the perspective theory will be discussed later in this chapter. The problems raised by the constancy theory will be considered in Chapter 4. Hotopf (1966) agreed that it is difficult to see differences and to appreciate changes in the sizes of the faces of the conventional form of the Necker cube. He pointed out, however, that if the transversals are elongated in such a way as to represent a two-dimensional projection of a rectangular, rather than a cube-shaped form, changes in apparent size are frequently detected.

An elongated form of the Necker cube is shown in Fig. 2.6**b**. In an ancillary study 112 members of a sample of 127 individual Os reported the square faces of this figure to differ in size depending upon the aspect in which the figure was seen. In each case the relative sizes assumed by the faces were such that the one

being apparently nearer seemed to be smaller than the one located further away. Although this might appear to be the converse of the outcome expected, it will be shown later that this is entirely consistent with a perspective interpretation of the form of the rectangular skeleton figure.

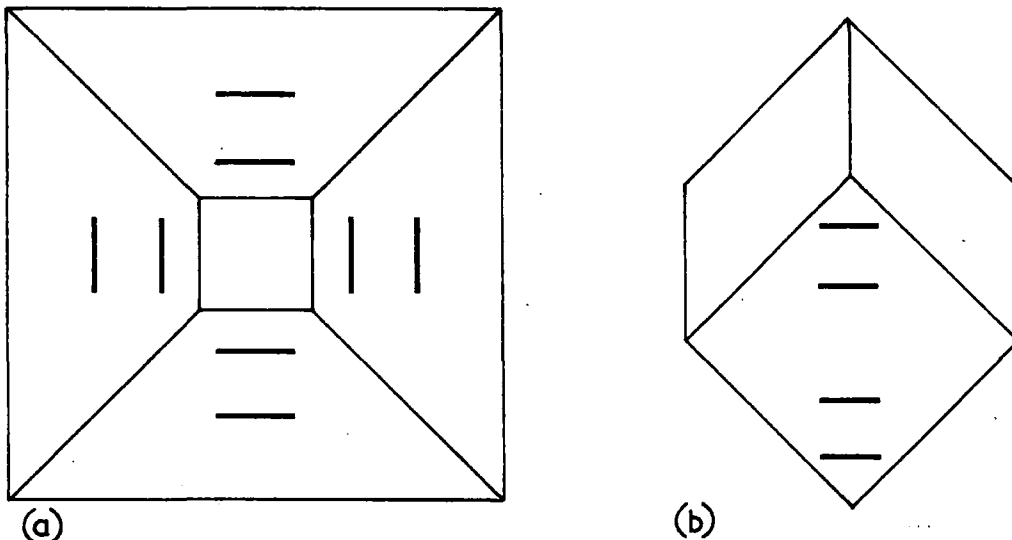


FIG. 2.7 TWO FIGURES, FEATURES OF WHICH APPEAR TO REVERSE IN DEPTH

The argument from reversability of aspect in depth provides a crucial test of the perspective theory. The demonstration of differences in apparent-size of the faces of Fig. 2.6b may be interpreted as confirming the influence of features indicative of depth upon the sizes assumed by forms which appear to be located at different distances. If the theory is valid, however, it should also predict changes in relative size to appear

in other figures, two examples of which are illustrated in Fig. 2.7. Fig. 2.7a reverses readily in depth; in one aspect it appears to represent a front-elevation drawing of an open-ended corridor, or box; in the other it appears to be the plan-elevation of a truncated pyramid. In each of these aspects the apparent-depths of the component parts of the pattern are different. When seen as a corridor, the larger square appears closer than the smaller, the sides receding backward into space. In its pyramid-aspect, the larger square appears further than the smaller and the sides project forward into space. Four pairs of lines, identical in length, are drawn upon those parts of the figure representing walls, or sides. The apparent-relative positions of each member of these four pairs of lines differ depending upon the aspect in which the figure is seen. Accordingly, their relative apparent-sizes should differ. Moreover, the nature of this difference should change as the figure alternates in aspect. 123 of the 127 members of our sample of Os reported that the pairs of lines did not appear to be of the same length. Irrespective of the aspect in which the figure was seen, however, they were unanimous in observing that the inner member of each pair of lines always appeared to be the longer.

Initially the reversible pattern illustrated in

Fig. 2.7b usually resembles the sides and floor of an incomplete box. Upon reversal it assumes an appearance somewhat reminiscent of an overhanging plinth. In each alternative form the floor, or base, differs in its location in apparent-depth. When seen as a box the upper part of the 'floor' is apparently further in space than the lower, the reverse being the case when it is seen as a plinth. Again, on the perspective theory, each member of the pairs of lines superimposed upon this figure should appear to differ in length depending upon which interpretation of its form is entertained and this difference should change in direction when it undergoes reversal in depth.

Method and procedure

To consider this prediction the apparatus devised for Experiment 1 was used again. Two versions of Fig. 2.7b were painted, as before, on sheets of clear plastic and placed against the background display containing the two horizontal slots. In one pattern the slots were closer to the upper part of the figure and in the other they were closer to the lower. In the first condition the upper slot was presented in a standard length of 100mm., in the second the lower slot was presen-

ted in a similar size. 100 individual Os were requested to adjust the variable length to equality in each location of the figure. In both conditions two situations were included. In the first, Os were asked to see the figure in a particular orientation and to 'hold' it in that aspect whilst making their adjustments, the alternative aspect being maintained in the second. A control situation was not used in this particular experiment but appropriate comparison data may be extracted from the sixth column of Table 2.1.

Results

The results entered in columns in Table 2.111 refer to the apparent relative lengths of the two pairs of lines according to the aspect in which the figure was seen. They reveal that the extent of distortion is not influenced in any way either by the positions of the lines with respect to the figure or by the depth aspect in which the figure is maintained.

TABLE 2.111

COMPARISON OF THE APPARENT-LENGTHS OF TWO PAIRS OF LINES
IN THE CONTEXT OF BOTH ASPECTS OF A REVERSIBLE FIGURE

LINES	:	UPPER PAIR	:	LOWER PAIR
Aspect maintained:		'Box'		'Plinth'
		'Plinth'		'Box'
\bar{X}	:	7.46	:	7.39
		7.31	:	7.43
$\delta\bar{x}$:	0.54	:	0.50
		0.51	:	0.49

DISCUSSION

Certain perceptual scaling mechanisms function so as to extrapolate information relating to the dimensions of features of the visual world. The perspective theory of illusions is based upon the assumption that these same mechanisms are brought into operation when analysing the informational content of two-dimensional spatial patterns but that they are inappropriate when required to function in this way. Accordingly, an illusion arises. The theory is empiricistic in nature since experience of concrete three-dimensional scenes

and structures is understood as transferring to abstract two-dimensional patterns. Hence, the relevant spatial scaling mechanisms come to operate in situations other than those responsible for the acquisition and development of their function.

In the introduction to this chapter it was suggested that, according to the perspective theory, veridical perception of three-dimensional space is achieved and maintained at the cost of illusory distortion of two-dimensional space. Implications similar to this were made by Piéron (1955) who argued that illusory distortions disappear completely when the patterns composing them are given meaningful connotations. When discussing the Poggendorff illusion, for example, Piéron stated that ".... if the two segments (of the oblique line) are made of rope passing behind a column and serving to pull a bucket out of a well, the illusion disappears completely. Consequently, I believe that one must not exaggerate the importance of optical illusions. I repeat, they have little connection with everyday life...." (p.76). Again, when considering the Müller-Lyer figure, which he also claimed not to become apparent when seen within a concrete context, Piéron observed ".... The Müller-Lyer illusion is a phenomenon which never has any influence upon our spatial activity. It is a curiosity the principle

upon which the illusion is based is of no spatial importance...." (pp.75 - 76). These and other statements with similar implications were based upon the experimental studies of Filehne (1898) and Ebbinghaus (1902) which Fisher and Lucas (1968) and Lucas and Fisher (1968) have discussed in detail elsewhere. Here the point should be made that all statements of this kind are entirely mistaken since it has been shown conclusively that illusions remain, similar in direction and undiminished in extent, when the contours which define them are embodied within meaningful spatial patterns with which they may be compared directly. In itself this casts some doubt upon the basic assumption of the perspective theory since features of both two- and three-dimensional space undergo similar distortions. Accordingly, it appears difficult to claim that veridical perception of the latter is achieved at the cost of illusory distortion of the former.

Nevertheless, if tenable, the perspective theory could be invoked to clarify, and perhaps solve, a number of unresolved perceptual problems. Important of these is the issue first raised by Rivers (1901 and 1905) in the attempt to distinguish between cultural and biological determinants of perceptual organisation. Rivers observed that the indigenous Torres Indians and the Todas, natives of Southern India, were differenti-

ally susceptible to the vertical-horizontal and Müller-Lyer illusions in comparison with Western control Os. With some exceptions the findings of Rivers have been replicated, most recently in the extremely comprehensive studies reported by Segall, Campbell and Herskovits (1963 and 1966). The theoretical position underlying these studies is almost identical with that upon which the perspective theory is based. Segall et al. refer to their version of it as 'the carpentered world hypothesis' observing "...In the carpentered western world such a great proportion of artefacts are rectangular (more correctly 'rectilinear') that the habit of interpreting obtuse and acute angles as rectangular surfaces extended into space is a very useful one. Such an inference pattern would generate many of the line drawings here tested. (The Müller-Lyer, two versions of the vertical-horizontal illusion, Sander's parallelogram and a figure described as 'the perspective drawing illusion' which resembles the Ponzo figure). In a culture where rectangles did not dominate, this habit might be absent.... Another cultural factor which might be related to illusions is two-dimensional representation of three-dimensional objects. Perspective drawing is a most persuasive feature of Euro-american culture. It is a substantial feature of the visual world from childhood on. Children in this

culture, from a very early age, attempt to make representations of this kind themselves. The techniques or conventions involved may be related to the habits of inference which some illusions illustrate" (p.71)

Segall et al. reported Western samples to be more susceptible to the Müller-Lyer illusion and to the distortion evident in Sander's parallelogram, the reverse being the case for the two vertical-horizontal illusions. In the context of the theory it is significant, perhaps, that the two groups were not distinguished by differences in the illusory features of the perspective drawing.

Effects arising from differential formal aspects of two-dimensional spatial patterns having three-dimensional connotations have been considered throughout this chapter. Accordingly, the findings should be relevant to any theory which invokes the influence both of depth features and of the formal perspective conventions used to represent them upon perceptual function. The first experiment was concerned with the Ponzo figure in which the upper member of two identical horizontal lines, seen against the background of an inverted V-shaped bracket, appears to be longer than the lower. The characteristic form of the distortion defining this illusion should be considered carefully, particularly when attempting to invoke perspective features to explain it. Of the two lines in the Ponzo

illusion, the one which appears further away is elongated in relation to the one which appears nearer.

The nature of this distortion appears to be paradoxical and Gregory drew attention to the contradiction which it seems to imply when observing ".... why should suggestion of greater distance produce increase in size when distant objects are typically seen as smaller with increasing distance? The theory predicts not an increase, but a decrease in the size of features having greater distance indicated by perspective but this is the wrong way round" (1966b, p.147)

He reaffirmed this view in stating ".... From this point the perspective theory goes off the rails. It states that depth is 'suggested' by the perspective features, and this 'suggestion' produces an expansion of the more distant features. But even if we allowed that a 'suggestion' could cause a size change, it would be the wrong way round because distant objects in the real world look smaller, not larger. In each case the traditional perspective theory gives exactly the wrong prediction" (1966a, p.78). At first sight this argument appears extremely convincing. Should it be tenable it would carry the implication that the explanatory features of the perspective theory are confounded. The assumptions and implications of this contrary view, however, appear to be based upon a mistaken

understanding of the nature of the relationship between the sizes which objects assume in relation to the distances at which they appear to be located. This error has been proliferated widely and its significance is such that it should be corrected.

The problem which requires consideration arises from the appearance of the Ponzo figure in which distortions of size become evident. The form of the figure is such that it is reasonable to propose these distortions to be commensurate with the distances at which the lines forming part of the figure appear to be located in depth. The apparently further line in the Ponzo figure is enlarged in relation to the line which seems nearer. Accordingly, the conclusion has been drawn that the obviously relevant relationship between apparent-size and -distance must necessarily imply rejection of the argument from perspective.

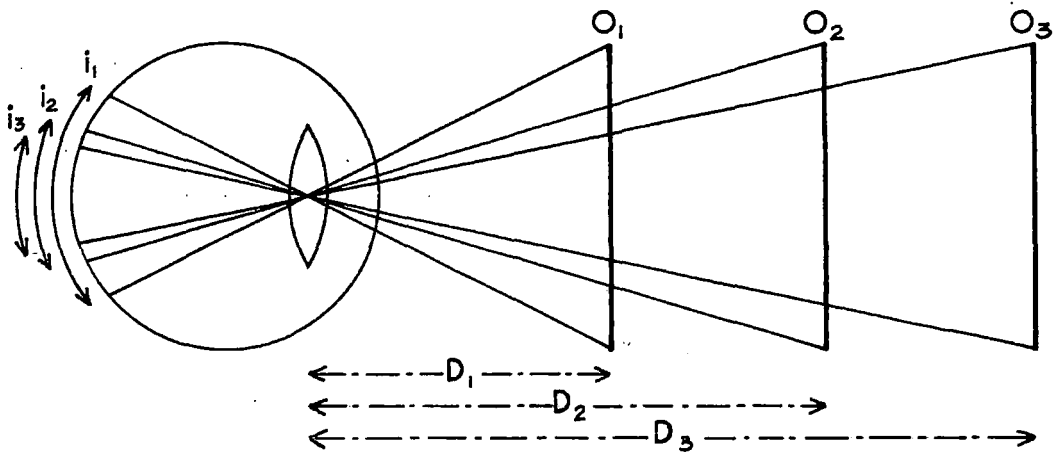


FIG. 2.8 RODS OF THE SAME LENGTH PLACED AT DIFFERENT DISTANCES FROM THE EYE OF AN OBSERVER

The nature of this relationship, however, may be somewhat less obvious than it appears at first sight. In relation to the eye, objects in the physical world assume different sizes depending upon the distances at which they are located. Objects located in different positions subtend different angles at the lens and the images arising from them, projected upon the retina, differ in size accordingly. The retinal analogue of any specified closer object is larger than that of an otherwise similar object located at a further distance. Referring to Fig. 2.8 the principle relating the retinal sizes of an actual object to the

physical distances at which it may be placed is thus simply:

$$i_1 \times D_1 = i_2 \times D_2 = i_3 \times D_3 = \text{constant} \dots (1)$$

where 'D' is the lateral distance of an object from the eye and 'i' the size of the retinal image to which it gives rise.

It is customary to refer to this relationship as the principle of Euclidean optics. To distinguish it in this way may lead to confusion, however, since all the principles developed here are essentially Euclidean in nature. The situation formalised by principle (1) is approached in experimental conditions in which relatively abstract materials are presented in spatial contexts lacking concrete cues. Actual objects seen in real-life contexts, however, tend to preserve their apparent-sizes, notwithstanding the distances at which they are placed. This well-known perceptual phenomenon is usually referred to as 'size-constancy'. It implies that the appearance of any particular object is maintained; thus, spatial patterns continue to assume the appearances both of what they are and of what they are known to be.

The mechanism underlying preservation of the appearances assumed by features of the visual world may

be understood as having a certain perceptual utility. As an adult person walks down the sidewalk, away from an Q, the height of the image cast by his figure upon the retina of the eye decreases two-fold for every doubling of his distance; accordingly, the cross-sectional area of his image decreases four-fold. In the course of so-doing he does not assume the appearance of a child, pygmy or a dwarf, however, rather his figure tends to remain of a similar apparent-size as he recedes into the distance. Only over large distances, such as when seen from a mountain-side, or from an aeroplane do people, trees, automobiles and houses lose the 'reality' of their appearance, becoming model- or toy-like.

It has frequently been argued that modification of the sizes of objects according to size-constancy should be commensurate with changes reflected in the distances at which they appear to be placed. Perhaps the most systematic analysis of the relationship between these two parameters of phenomenal space was initiated by Adelbert Ames. Describing the view of his mentor, Ittelson (1951) observed "....O must know the size of the object of regard. This enables him to infer its distance" (p.54). He emphasises this point later in describing the situation which has become known as ".... 'the thereness of that' demonstr-

ration, thereby laying stress on the fact that the apparent-distance of the perceived object (its 'thereness') is determined by the perceived nature of the object (its 'thatness')" (p.61).

Again making reference to Fig. 2.8, the principle which describes the phenomenon of size-constancy may be stated as follows:

$$\frac{O_1}{D_1} = \frac{O_2}{D_2} = \frac{O_3}{D_3} = \text{constant} \dots (2)$$

where 'O' refers to the apparent-size of a specified object and 'D' to the distance at which it appears to be located with respect to the eye of an observer. The form in which this relationship is expressed is such that the term 'size-constancy' may be regarded as something of a misnomer since it makes reference to one aspect of the appearance of objects only (their assumed sizes), to the exclusion of specification of the other (their assumed distances). Accordingly, it might reasonably be replaced by the more definitive expression 'size-distance invariance'. This view was originally implied by Martius as long ago as 1889 but, while it has been reaffirmed on many occasions since, the term 'size-constancy' continues to remain in gen-

eral use.

This far, the formal nature of relationships between the real and apparent-sizes of concrete and abstract objects located at different distances in the real world have been considered. A further relationship between apparent-size and apparent-distance was submitted to detailed experimental study by Emmert. The principle proposed by him has frequently been claimed to hold good for abstract situations but to break-down in the concrete conditions of real-life. Deviations from the relationship between apparent-size and -distance, formulated in principle (2) above, were observed by Martius. Accordingly, Carr (1935) argued for a limited application of Emmert's law. A definitive study of size-constancy was made by Holway and Boring (1941) who reported that distortion attributable to the constancy mechanism was maximal in 'natural' binocular conditions of viewing and minimal in monocular vision for abstract stimuli viewed through a reduction tunnel fitted with an artificial pupil. There are a number of misunderstandings here, principal of which derives from confusion over the nature and implications of Emmert's law. The position may be clarified as follows:

In his monograph 'Grossenverhältnisse der Nachbilder', published in 1881, Emmert wrote ".... The increase

in the size of an after-image of an object with an increase in distance or its decrease with a decrease in distance, rests upon the fact that, once an after-image is developed on the retina, so long as it remains, it retains the same size on the retina. After outward projection this after-image itself becomes an object, if one can so speak; the angle under which it is seen as removed outward, remains constant as a consequence of the unchanging size of the retinal image, and the size of the projected image depends entirely upon the distance of the object upon which it will be developed ..."
 (p.448).

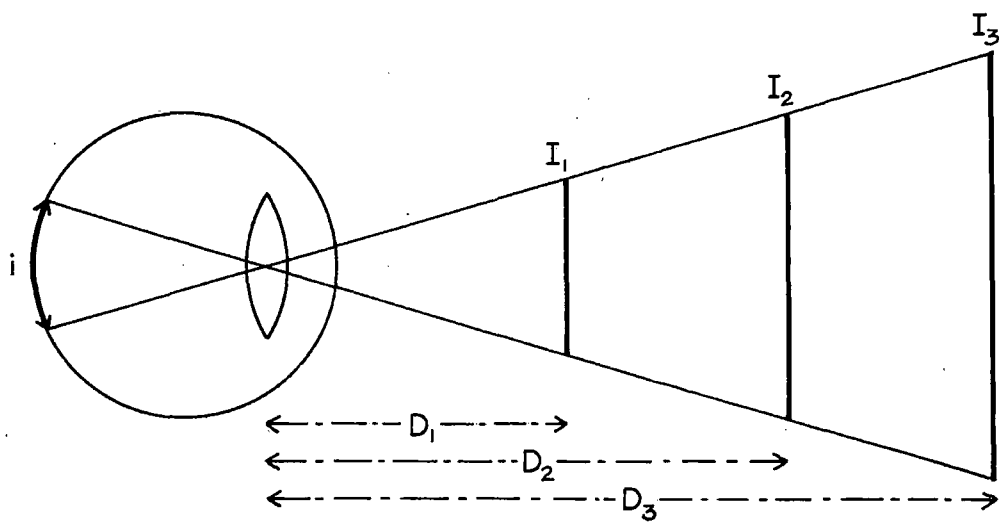


FIG. 2.9 THE SIZES ASSUMED BY AFTER-IMAGES PROJECTED UPON SURFACES PLACED AT DIFFERENT DISTANCES

From Emmert's statement it is clear that his experiments were concerned with ectopic after-images, developed upon the retina and projected upon plane surfaces placed at different distances from the eye, rather than with actual objects located at different positions in space. He proposed a simple functional relationship between the two spatial parameters of after-images; namely, the sizes which they appear to assume and the distances to which they are projected. Referring to Fig. 2.9 this relationship may be stated as:

$$\frac{I_1}{D_1} = \frac{I_2}{D_2} = \frac{I_3}{D_3} = \text{constant} \dots (3)$$

where 'I' is the apparent-size of the after-image and 'D' the distance from the eye of the surface upon which it is projected.

Controversy has arisen over what Emmert actually did, what phenomenon he was referring to and what his 'Law' was intended specifically to imply. Boring (1940) drew attention to this and made an extremely clear statement describing Emmert's law and its connotations. Subsequent to criticism by Young (1948, 1950 and 1951), however, Edwards and Boring (1951) appeared to become uncertain of what Emmert intended originally to propose. The confusion may have been reinforced by

Emmert's reference to an after-image itself becoming an object but, in the main, it appears to derive largely from failure to recall that his studies were concerned exclusively with after-images rather than with retinal projections of real objects.

The three situations under consideration may be summarised as follows:

(i) When the size of an object is controlled there is a constant relationship between the product of the size of the retinal image cast by it and the distance at which it is actually located from the eye

(ii) When the size of an object is controlled there is a constant relationship between the quotient of the size assumed by it and the distance at which it appears to be located with respect to the eye

(iii) When the size of the retinal image due to an object is controlled by developing it as an after-image upon the retina there is a constant relationship between the quotient of the apparent-size of the object and the distance of the surface upon which it is projected

To return to Gregory's attempted refutation of the perspective theory, the principle invoked in which is

that designated (1) above. The nature of this contrary argument is such as to rest squarely upon the assumption that the two horizontal lines of the Ponzo figure are actual objects casting images of different sizes upon the retina. But the lines of the Ponzo figure are not objects displaced physically in depth. Nevertheless, they appear to be so and, moreover, they appear to differ in size. Despite these differences the retinal images due to each of the two lines are identical in length. Since retinal size is controlled, the relationship relevant to their differential appearance is that developed in principle (3) above. The line which appears further also seems larger and that which appears nearer seems smaller. Thus, an acceptable explanation of the form assumed by the Ponzo figure follows directly from Emmert's law. Accordingly, the mistake appears to arise from application of a principle which is inappropriate for a situation in which retinal size is equated.

Gregory and others have extended their considerations to the Müller-Lyer figure, which provided the subject of the second experiment reported in this chapter. Again, rejecting the relevance of perspective, Gregory argued that the shaft enclosed within ingoing brackets resembles the outer edge of a building, while that bounded by outgoing brackets is reminiscent of the inner

corner of a room. Accordingly, he proposed that the apparent-lengths of shafts bounded by oblique lines subtending different angles should be closely related to their apparent locations in depth. In the appropriate experiment this prediction received overwhelming confirmation. Here the point should be raised, however, of exactly what phenomenon was under observation in this particular experiment.

The shafts of the Müller-Lyer figure appear to differ in length. The one bounded by obtuse brackets appears longer than that bounded by acutes. As in the case of the two lines contained within the Ponzo figure, the images cast upon the retina by each of the shafts are identical in length. Hence, here again retinal size is controlled and the relevant principle relating apparent-size and apparent-distance is that of (3) above. According to this, a line which appears longer should also appear to be further away and one which is shorter, nearer. Reconsideration of the extremely high correlations reported by Gregory relating the apparent-sizes of the shafts of the Müller-Lyer figure to the distances at which they appear to be located in depth seems, therefore, to indicate confirmation of Emmert's law rather than to provide evidence in favour of variability in apparent-size arising from inappropriate operation of the constancy mechanism

Neither of the first two experiments described in this chapter provides any evidence against the influence of perspective features upon illusory spatial distortion. They indicate rather that there is a formal relationship between perspective, constancy and the principle relevant to the apparent-sizes assumed by after-images developed upon the retina, these subsequently being projected upon actual physical surfaces, located at different distances. The preliminary study to the third experiment indicated that the faces of the Necker cube appear to undergo changes in size. The nearer face seems smaller than the further face, this again being entirely in accordance with Emmert's law, since as before retinal size is controlled. At this point, however, the argument from perspective does, in fact, break down. According to the perspective theory, the component elements of the reversible figure used should serve to induce distortion commensurate with differential apparent-depth. Since the depth features of this figure alternate as its form reverses in aspect, however, the direction of the illusion seen in the two horizontal lines should change appropriately. An illusory distortion undoubtedly became apparent in this figure but it remained identical in direction and extent irrespective of the differential appearance of the figure in depth. Hence, the prediction concerned with indica-

ting the relative sizes of forms seen at different apparent-distances was not supported. Accordingly, we are forced to the conclusion that, in spite of the simplicity and persuasiveness of the perspective theory and notwithstanding the fact that it can be maintained against former criticisms of its validity and relevance to features of visual space perception, it cannot be brought to account in providing an entirely acceptable explanation of the distortions evident in illusions.

CHAPTER 3

AN EXPERIMENTAL COMPARISON OF RECTILINEAR AND CURVILINEAR ILLUSIONS

The most persuasive of the many theories formulated in the attempt to explain the distortions seen in illusions is that which invokes the influence of perspective elements embodied within their configurations. This theory was first proposed by Thiéry (1896) who drew attention to the similarity of some illusions to two-dimensional projections of concrete objects and three-dimensional scenes. The most well-known and widely studied of all illusions, that first described by Müller-Lyer in 1889, reminded Thiéry of the cross-member and trestle legs of a saw-bench. The closeness of this resemblance led him to suggest that familiarity of meaningful objects and real-life scenes might conceivably be influential in inducing distortion in certain two-dimensional drawings.

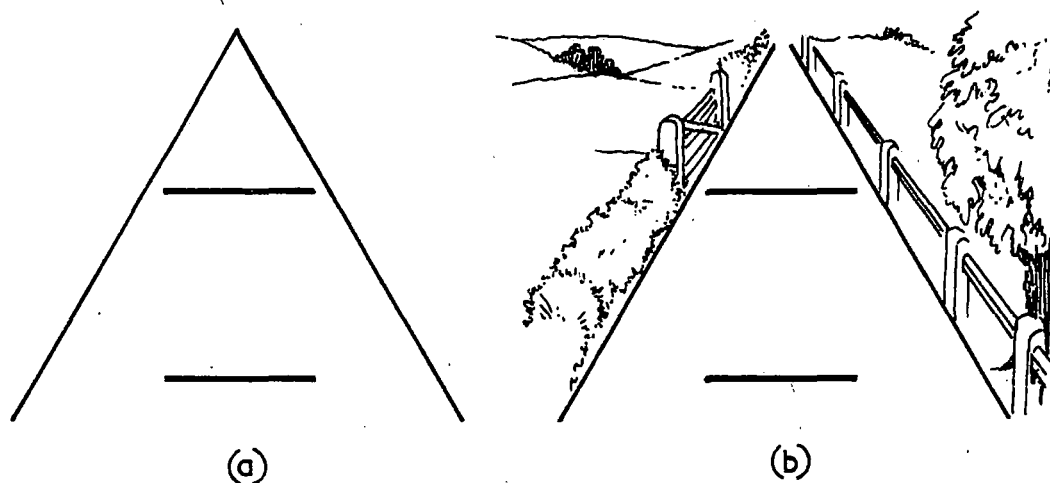


FIG. 3.1 THE PONZO ILLUSION AND A PERSPECTIVE PROJECTION OF A TYPICAL THREE-DIMENSIONAL SCENE

The illusion to which the perspective theory should be most obviously relevant appears in the Ponzo (1912) illusion, reproduced in Fig. 3.1a. This pattern is defined by two horizontal lines enclosed within an inverted V-shaped bracket. Although the two horizontal lines are identical in length, under the influence of the illusion, the upper line appears to be appreciably longer than the lower. The Ponzo figure is strongly reminiscent of projections of such scenes as road-ways, or railway-tracks, the lines representing which appear to converge as they

recede into the distance. Lines superimposed upon perspective drawings of three-dimensional scenes are distorted in the same way as those which form part of the Ponzo figure. An example of distortion of this kind apparent in a two-dimensional drawing of a typical three-dimensional scene is illustrated in Fig. 3.1b. Here, as in the conventional Ponzo figure, the upper line appears to be somewhat longer than the lower.

The importance of the perspective theory extends beyond its original premise. Rivers (1901 and 1905) observed indigenous Torres and Todas Indians to be differentially susceptible to illusory distortions in comparison with subjects raised in Western cultures. He proposed that these differences arise directly as a consequence of the experience of the spatial features of typical environments. More recently the findings of Rivers have been reaffirmed in the long-term cross-cultural studies undertaken by Segall, Campbell and Herskovits (1963 and 1966), their formulation of 'the carpentered world hypothesis' being expressed as follows:

".... In the carpentered Western world such a great proportion of artefacts are rectangular that the habit of interpreting obtuse and acute angles as rectangular surfaces extended into space is a very useful one In a culture where rectangles did not dominate, this habit might be absent Another cultural factor which might

be related to illusions is two-dimensional representation of three-dimensional objects. Perspective drawing is a most persuasive feature of Euro-american culture. It is a substantial feature of the visual world from childhood on. Children in this culture, from a very early age, attempt to make representations of this kind themselves. The techniques or conventions involved may be related to the habits of interference which some illusions illustrate" (1966, p.71). The view expressed here may be understood as a logical extension of that suggested by Thiéry and the results of the extensive studies reported by Segall et al. testify strongly to its validity.

In the majority of experimental studies of illusions rectilinear figures have been employed. Thiéry and others attempted to extend the implications of perspective by considering the Müller-Lyer (1889), Ponzo (1912), Poggendorff (1860), Hering (1861), and Wundt (1896) figures specifically in these terms. Relatively few attempts have been made to evaluate the distortions apparent in curvilinear figures, however, and, as far as we are aware, no such figures have been studied cross-culturally. The purpose of the present chapter is to initiate consideration of the possibility of illusory spatial distortions being apparent in figures other than those with which they are usually asso-

ciated.

Method

As applied to the Ponzo and other illusions the explanatory principle of the perspective theory rests upon the similarity between the angular components of two-dimensional patterns and projections of scenes and structures actually having extension in three-dimensional space. Being apparently situated at different distances, the two horizontal lines embodied within the Ponzo figure appear to differ in size, the further line seeming to be longer than the nearer. In Fig. 3.2 the two horizontal lines of the Ponzo illusion have been placed in contexts which are other than angular. Figs. 3.2a and b are defined by curved rather than straight lines, and Fig. 3.2c by two pairs of vertical bars. Inspection of each of these figures suggests that an illusion similar in nature to that seen in the Ponzo figure is clearly evident. Accordingly, the problem becomes that of measuring the extents of these illusory distortions.

Apparatus

An apparatus was constructed embodying two horizontal slots seen as white bars against a black background. These slots were 5mm. wide and they could be adjusted in length from 70 to 130mm. symmetrically about their centres. The background against which the slots were placed was 610mm. square. The angle, the two sets of vertical bars, the concave and the convex patterns were painted in white line upon sheets of a transparent plastic material. When these were placed against the background the slots could be seen clearly through them. Thus, the over-all patterns assumed by the background and the displays superimposed upon it closely resembled the three forms illustrated in Fig. 3.2 and the conventional Ponzo illusion shown in Fig. 3.1a. A further sheet of plastic omitting any lines was introduced also, this providing the appropriate control situation.

Procedure

A total of 100 individual subjects participated in this experiment. Twenty-three of these were University students ranging in age from 18 to 27 years, eight of

whom were female. The remaining subjects were selected essentially at random from the populace of Newcastle upon Tyne. They ranged in age from 19 to 69 years, forty-three being female. All subjects had normal vision. They were shown the five displays individually, the upper horizontal slot being presented in a standard length of 100mm. In each case subjects were asked to adjust the lower slot to such a position that it appeared to be of the same length as the upper. Initial positions of the lower variable slot were presented in a randomly determined order throughout the whole range of possible adjustment. All subjects made ten adjustments in relation to each of the five displays, the order of presentation of which was randomised appropriately. This order was changed for each subject participating in the experiment.

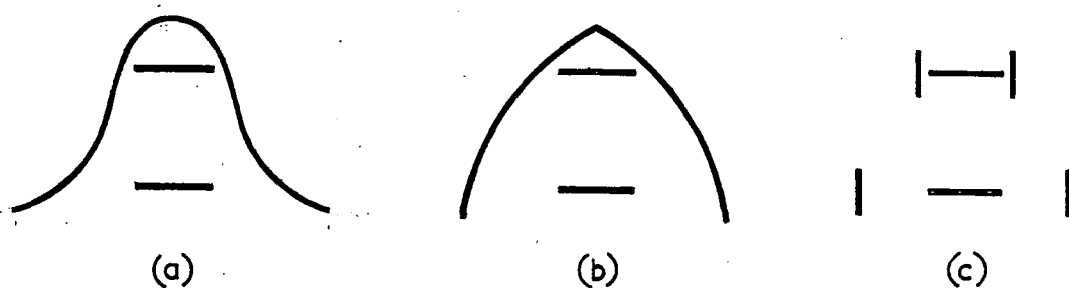


FIG. 3.2 THREE NEW PONZO-TYPE ILLUSIONS

TABLE 3.1

THE EXTENT TO WHICH EACH LOWER HORIZONTAL LINE WAS ADJUSTED SO AS TO APPEAR OF THE SAME LENGTH AS THE UPPER

DISPLAY	1(a)	2(a)	2(b)	2(c)	Control
Adjustment of \bar{X}	13.44	12.57	10.85	8.57	0.37
lower line $\delta\bar{X}$	0.52	0.41	0.31	0.38	0.35

Results

The results of this experiment are entered in Table 3.1. Numerical values expressed in units of mm. indicating the extent to which each lower line was adjusted to a length in excess of the upper, are shown for all four experimental displays. Alongside these are the data referring to adjustment of the variable line in the control condition. The mean values (\bar{X}) refer to the combined judgements of the total sample of subjects, each of whom made ten judgements. The standard errors of estimate ($\delta\bar{X}$) associated with the mean values are entered beneath them. Sophisticated statistical treatment of data of such clarity is almost gratuitous. They show that an illusory spatial distortion, of the

kind usually associated with the conventional Ponzo figure became apparent in both curvilinear displays and in the pattern which embodies two pairs of vertical bars. The mean values of all these distortions considered against their standard errors indicate clearly that in a statistical sense each differs from the control situation in which no additional contour was present. Accordingly, it may be concluded that illusory distortion in the relative apparent-lengths of two horizontal lines embodied within the contexts of further contours has been demonstrated.

DISCUSSION

The explanatory features of the perspective theory rest upon the assumption that the organisation of the perceptual mechanisms underlying the appearance of illusions is initiated and developed as a consequence of experience of features of three-dimensional space. Illusory distortions become evident in line-drawings prepared upon two-dimensional surfaces. Certain line-drawings resemble plan-, front- and side-elevation projections of three-dimensional objects and solid structures. In the physical world, different parts of such

structures are located at different distances in relation to the eyes of an observer. Accordingly, the retinal images due to them differ in size. In general, those parts which appear to be closer are larger than others, which are seemingly more distant. Certain perceptual scaling mechanisms are brought into operation when judging the sizes of objects in relation to their distances. The central and most important concept of the perspective theory is that these same mechanisms operate when observing two-dimensional patterns. Unfortunately, the characteristic functional modes of these spatial scaling mechanisms fail to be appropriate when they operate in such a way as to extrapolate information from some line-drawings. When this proves to be the case an illusion arises. Accordingly, it may be argued that, according to perspective theory, the price paid by the visual projection system for veridical perception of three-dimensional space is consequential illusory distortion of two-dimensional space.

As referred to in introducing the topic of this chapter the perspective theory has been invoked in a variety of different ways since it was first proposed. It provides the only theoretical rationale for those cross-cultural studies which have shown people living in variously structured environments to be differentially susceptible to illusions. The only serious chal-

lenge to the theory was made by Gregory (1966a) who sought, first to demonstrate it to be invalid since the prediction which it makes of the nature of the distortion expected to become apparent in the Ponzo illusion seems to be the reverse of that usually seen (according to Gregory, on the perspective theory, the upper horizontal line in the Ponzo figure should appear shorter not longer than the lower) and, secondly, to replace it with his version of the Tausch (1954) theory according to which illusions arise as a consequence of the inappropriate operation of the mechanism responsible for size-constancy. In Chapter 4 it will be suggested that this contrary view proceeds from mistaken assumptions. The point of the expected nature of the Ponzo illusion on a perspective interpretation of its form is taken up and it is concluded that the characteristic appearance of this particular illusion is in no way at variance with the perspective theory.

It is debatable also whether, or not, the results of the experiment reported here may be interpreted as confounding the perspective theory. The conventional Ponzo illusion undoubtedly contains strongly defined features which are reminiscent of scenes having extension in depth;- that is to say, it resembles a two-dimensional projection of a three-dimensional spatial pattern. The curvilinear patterns might conceivably be

interpreted in a similar way and in solid form the upper part of each of these would usually be located at a somewhat further distance than the lower. A perspective interpretation of the form of two pairs of vertical bars is possible also but it is perhaps somewhat less likely. Certainly, if present at all, any depth features apparent in this figure are minimal in comparison with the others. Nevertheless, a significant illusory distortion of lines placed within them undoubtedly remains clearly evident.

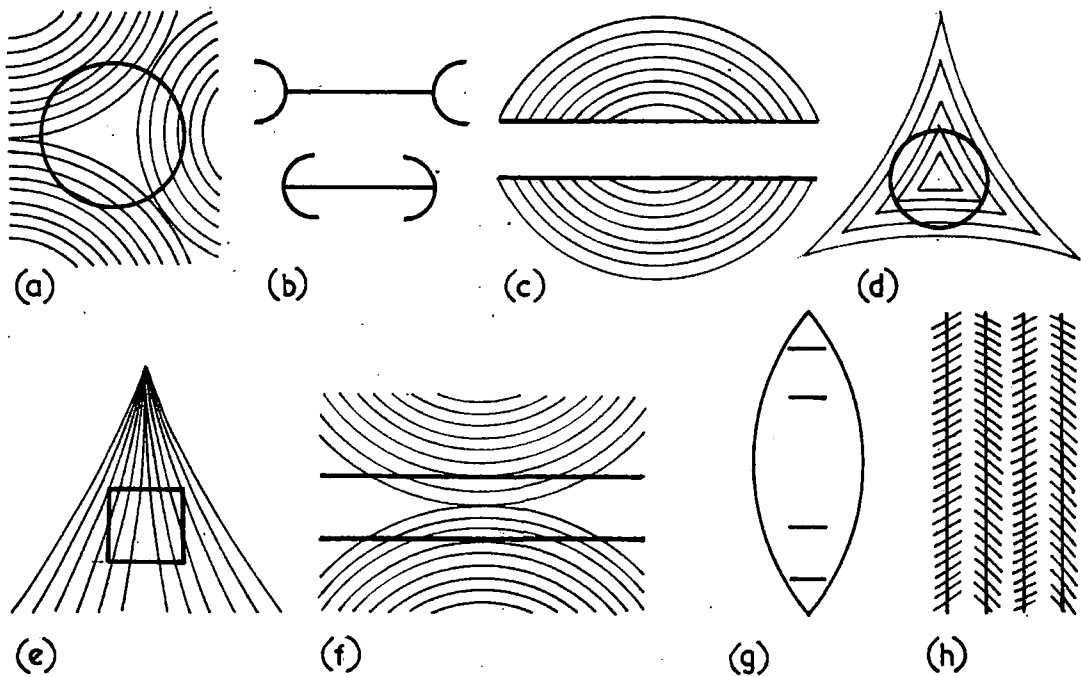


FIG. 3.3 A NUMBER OF WELL-KNOWN ILLUSIONS MODIFIED SO AS TO INCLUDE CURVED RATHER THAN STRAIGHT LINES

As described above, the hypothesis of the 'carpentered world' rests upon the same theoretical foundation as that of 'the perspective theory'. Invoked by Segall et al. it implies that we (Westerners) should be more susceptible to illusions which arise in rectilinear figures since we have somewhat greater experience of straight and angular patterns than those who dwell in more primitive environments. The ecologies of the societies studied by Rivers, by Segall et al. and by many others concerned to delineate the cultural determinants of perception, however, were liberally endowed with naturally occurring curvilinear objects. Moreover, such primitive peoples as these are extremely familiar with a variety of curved artefacts, with circular-section structures and with curvilinear projections.

The distorting components of the curvilinear patterns used in this experiment may be interpreted as projections of forms having extension in depth. They may, however, also be understood as representing structures more familiar to those dwelling in primitive societies than our own. Accordingly, the argument from the characteristic rectilinear nature of typical Western environments seems somewhat questionable. This is reinforced by the distortions apparent in each of the eight patterns illustrated in Fig. 3.3. These are all modified forms of otherwise well-known illusions. The distor-

ting aspects of the original versions of these patterns are all defined by straight lines. Here these have been replaced throughout by curves. The rectilinear form of Fig. 3.3a was illustrated by Luckiesh (1922), b by Müller-Lyer (1889), c by Wundt (1896), d by Gatti (1926), e by Ehrenstein (1924), f by Hering (1861), g is a 'double' version of one of the curvilinear patterns studied in this chapter and h was described by Zöllner (1860). The similarity of the distortions evident in these figures with those in the original illusions is such that it is difficult to believe that they should not be closely related. If this were the case then it would almost certainly follow that the perceptual scaling mechanisms responsible for their being at variance with their denotable physical forms either are the same or operate in similar ways. Hence, we are forced to the conclusion that the carpentered world hypothesis, along with other theories which appeal to the influences of typical depth features in inducing illusory spatial distortions, requires reconsideration.

CHAPTER 4

ILLUSIONS AND SIZE-CONSTANCY

Although the possibility of these two modes of perceptual organisation being related had been implied previously, the first systematic attempt to associate the phenomena of constancy with illusory spatial distortions was made by Tausch (1954). Reporting experiments and describing demonstrations he illustrated the mode of operation of a mechanism according to which certain systematic distortions are introduced into perceived aspects of the visual world. This he referred to as a 'spatial correcting mechanism'. Tausch suggested that this mechanism transfers in operation from three-dimensional spatial patterns, which constitute real-life scenes and concrete objects, to abstract two-dimensional illusory-figures. Thus, so conceived, the mechanism comes to operate independently of the conditions responsible for its initiation and development. Tausch's view was a reversal of that usually taken of illusions in that their relevance to concrete, three-dimensional scenes rather than to abstract, two-dimensional spatial patterns was emphasised. Accordingly, it provided a necessary corrective to the observations of Filhene (1898) and Piéron (1955) who claimed mistakenly that illusions are not

seen as such when their constituent spatial features are embodied within real-life scenes.

Subsequent to publication of Tausch's significant paper a number of observations and experimental studies, including those of von Holst (1957) and Kristof (1961), have been made in the attempt to extend and generalise application of the principle of constancy to explanation of the spatial distortions which appear in illusory-figures. Most recent and consistent of those who believe that constancy can be brought to account in explaining illusory distortions is Gregory (1963 and 1966 a and b) who first rejected all existing theories and subsequently redescribed and extended the argument introduced by Tausch. The widespread publicity received by Gregory's version of the constancy theory and the extent to which it has become subscribed to are such that it is timely to make a detailed appraisal of its provision of a valid and comprehensive explanation of the spatial distortions which underlie the geometrical illusions.

Gregory distinguishes between the spatial distortions which appear in line-drawings embodying geometrical illusions drawn upon two-dimensional surfaces from those which become apparent in such figures as the Necker cube which, when drawn as two-dimensional projections with luminous paint and seen without any background texture, or when constructed in the form of three-dimensional

models, continue to reverse in aspect with attendant changes in apparent-size. Line-drawings, and photographs, he argues, are "perceptually paradoxical" since they "are seen to depict objects as if they lay in three dimensions, and yet at the same time they appear flat, lying in the plane of the paper". Gregory accounts for spatial distortions of this kind by postulating the mechanism of 'primary constancy scaling', observing the mode of operation of this mechanism to be "set by perspective or other features normally associated with distance. These features can be at variance with apparent distance in special cases, such as the illusion-figures". (1963, p.680). The mechanism of 'secondary constancy scaling', on the other hand, is set simply by apparent-distance and, according to Gregory, is revealed by the demonstration in which size-changes become evident in the three-dimensional skeleton cube according to which face appears to be relatively nearer, or further away. Thus, to account for spatial distortions, Gregory postulates two mechanisms, one being set by depth features and being at variance with apparent-distance, the other being set directly by apparent distance and thus capable of being subsumed under Emmert's law. (1881). The primary system, Gregory observes, "seems to be primitive, and to be mediated by neural systems situated early in the perceptual system"

(op.cit. p.680), while the secondary system is understood to depend upon modifications of perceptual organisation which are initiated and which develop within the course of experience.

Gregory's interpretation of the constancy theory is based thus upon two 'explanatory' concepts, attendant upon which are two independent perceptual mechanisms. These will be referred to henceforth as:

- (i) 'Primary constancy scaling'
- and (ii) 'Secondary constancy scaling'

Each of these aspects of the theory generates predictions which may be considered logically and tested experimentally.

EXPERIMENT 1

Having dismissed both the principles of perspective and Emmert's law as providing acceptable and comprehensive explanations of illusory spatial distortions, Gregory postulates the mechanism of primary constancy scaling to operate in accordance with perspective and other features of spatial displays usually associated with apparent-distance. He claims that when such fea-

tures are at variance with apparent-distance, as they are in certain illusory-figures drawn upon two-dimensional surfaces, an appropriate distortion appears. Primary constancy scaling refers to the perceptual mechanism underlying the well-known phenomenon of size-constancy, usually described as the tendency of objects to maintain their apparent-sizes irrespective of the distances at which they are placed. Understood in this way the influence of constancy is to enlarge the size of an object, or spatial pattern with increasing distance. Since the apparently further line in the Ponzo figure, (1912), for example, appears to be larger than the apparently nearer line, this principle appears to provide a consistent explanation of this and a number of other illusory spatial distortions.

Gregory placed a good deal of weight in favour of this view upon the results of an experiment in which the Müller-Lyer illusion (1889) with different angles of bracketing fin was presented in such a way that both the magnitude of the illusion and the apparent location of the shaft in depth can be measured. Correlation of these two measures revealed an extremely significant relationship between them, this leading Gregory to observe ".... The extent of the illusion follows the amount of recorded depth very closely, for both directions. We may regard this result as strong evidence for relating

the illusion to perspective depth" (1966a, p.95)

The Müller-Lyer figures, he suggests, resemble the corners of rectilinear solid structures which appear to have extension in three-dimensional space. Understood in this way, the shaft bounded by outgoing arrow-heads takes on the appearance of the inside corner of a room while that bracketed by the ingoing arrow-heads looks like the outside corner of a building. It is assumed, therefore, that the ends of the arrow-heads determine the distances of the reference-planes against which the figures are seen. Thus, the shaft bounded by outward-flaring arrows appears to project backwards, away from the observer and that bounded by inward-flaring arrows appears to project forwards, towards Q. Being situated apparently nearer and further away, the shafts bounded by inward- and outward-flaring arrow-heads appear to be shorter and longer respectively.

If the Müller-Lyer figure were, in fact, to be seen as having extension in depth, then certain predictable distortions should appear within it. Gregory confines himself to consideration of the distortions undergone by the shafts which, understood in this way, define the corners of rectilinear structures, but why apparent-elongation should be confined to the shafts of the figure is not made clear. Spatial distortions arising from differential apparent-depth in the Müller-Lyer figure might

reasonably be expected to apply to the overall aspect of the figure rather than being restricted to the length of the lines joining the tips of the arrow-heads. Accordingly, the principle of primary constancy scaling generates a number of predictions which may be considered experimentally.

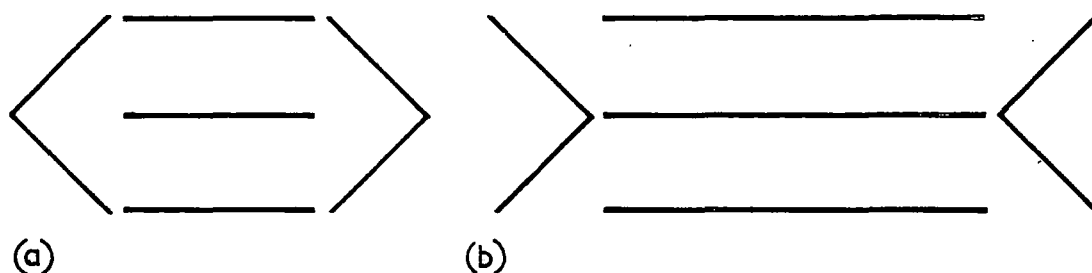


FIG. 4.1 THE BRENTANO VERSION OF THE MÜLLER-LYER FIGURES EMBODYING ADDITIONAL LINES

First, conceived of as defining surfaces projecting into space, the planes bounded by the arrow-heads of the Müller-Lyer figure should themselves undergo distortion, since it is in these regions of the figure within which any depth features become apparent. These depth features are in given directions, one representing outgoing, the other incoming, plane surfaces; hence, the principle of primary constancy scaling makes definitive predictions as to the nature of any distortion which should appear

as a consequence of them. The pattern shown in Fig. 4.1 is formed by the addition of three vertical lines, equal in length, to Brentano versions of each of the two Müller-Lyer figures. (1892). The predictions from the constancy theory relevant to the distortions in these figures are that the central vertical line in Fig. 4.1a should appear shorter than the outer lines, while the central line in Fig. 4.1b should appear longer than the outer lines.

These predictions refer to distortions expected to appear in parts of the Müller-Lyer figures which, if interpreted as resembling two-dimensional projections of three-dimensional rectilinear structures, correspond to the 'walls' of such structures.

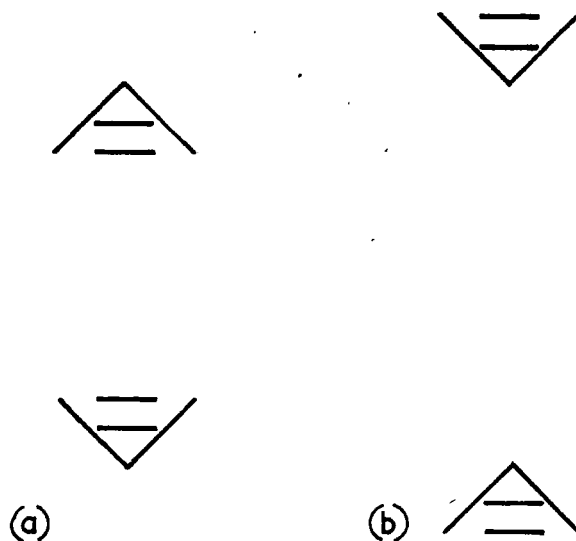


FIG. 4.2 THE BRENTANO VERSION OF THE MÜLLER-LYER FIGURES EMBODYING PONZO ILLUSIONS

Further predictions are concerned with related distortions which should become apparent in the parts of these figures which, if interpreted in this way, represent 'floors' and 'ceilings'. As the walls, these plane surfaces should also appear to project inwards and outwards into three-dimensional space. For the figure with ingoing arrow-heads the ceiling and floor should project backwards, away from the observer, the reverse being the case for the figure with the outgoing arrow-heads. As before, any spatial patterns superimposed upon them should undergo predictable distortions. Line-drawings appropriate for consideration of these predictions are shown in Fig. 4.2. They are formed by adding horizontal lines to the Brentano version of the Müller-Lyer illusion in such a way as to represent special versions of Ponzo illusions. According to primary constancy scaling, lines which are apparently nearer should also appear to be shorter than those which appear to be further away. Hence, the relevant predictions are that in Fig. 4.2a the outer horizontal lines should appear to be shorter than the inner lines, the reverse being the case for Fig. 4.2b.

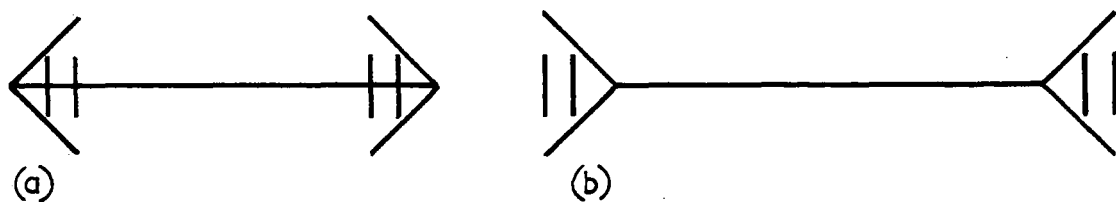


FIG. 4.3 MÜLLER-LYER FIGURES EMBODYING PONZO ILLUSIONS

The Brentano version of the Müller-Lyer illusions was used in Figs. 4.1 and 4.2 since omission of the shaft is reported not to influence the nature and extent of apparent-elongation and -foreshortening. The absence of the shaft joining the tips of the arrow-heads, however, might conceivably introduce modifications into the Müller-Lyer figure which render it difficult to maintain a three-dimensional interpretation of its form. Certainly, except perhaps when buildings are undergoing demolition, it is unusual to see corners of buildings without supporting walls and corresponding edges. When the shafts are replaced in the Müller-Lyer figure with interpolated horizontal lines, the patterns become those shown in Fig. 4.3. In Fig. 4.3b the prediction referring to the nature of any apparent distortion is the same as that made previously in the case of the unshafted figure. On a depth

interpretation the planes enclosed by the arrow-heads appear to project inwards, towards the observer, hence, the outer horizontal lines should appear shorter than the inner lines. In a projection of the kind shown in Fig. 4.3a, however, the planes representing the floor and ceiling would be obscured by those representing the walls. Accordingly, in relation to this figure the relevant prediction is that the straight horizontal lines should appear to bend in appropriate directions.

Method and procedure

The six patterns illustrated in Figs. 4.1, 4.2 and 4.3 were prepared in the form of drawings in black line on white paper. These were presented individually to each member of a sample of 50 psychologically naive Os, who were asked to judge the apparent relative lengths of the appropriate lines.

Results

The results of this experiment are shown in Table 4.1. They appear to be so clear as to render sophisticated statistical treatments gratuitous. First, all 50 Os judged the outer lines of Fig. 4.1a to appear longer than the inner line, the reverse being the case for 47 Os in Fig.

4.1b. This outcome is entirely consistent with a depth

TABLE 4.1

JUDGEMENTS OF THE RELATIVE APPARENT-LENGTHS OF LINES
INTERPOLATED WITH VERSIONS OF THE MÜLLER-LYER FIGURE

Figure	Judgements indicating		
	Inner longer :	Outer longer :	Equality
4.1 (a) :	0	50	0
4.1 (b) :	47	0	0
4.2 (a) :	0	48	2
4.2 (b) :	49	0	1
4.3 (a) :	0	49	1
4.3 (b) :	49	0	1

interpretation of these figures. Again, 48 Os judged the outer lines to appear longer in Fig. 4.2a and 49 judged the inner lines to appear longer in Fig. 4.2b. In this latter figure, however, the inner horizontal lines being apparently further away should appear to be longer than the outer lines which appear to be nearer. The relative apparent-length of these lines is thus in the reverse direction. Hence, the prediction is supported for Fig. 4.2b but not for Fig. 4.2a. The lines added to

shafted versions of the Müller-Lyer illusion in Figs. 4.3a and b are seen in a way essentially similar to that of the unshafted figures. Each O was asked specifically to consider if any of the horizontal lines in Fig. 4.3a appeared to undergo bending; none reported seeing them in this way.

In the case of each spatial pattern considered, the lines closest to the tips of the angles are seen to be longer than those further away. Assuming that these lines become associated with plane surfaces, parts of which appear to be located at different distances, the apparent-relative lengths of lines drawn upon them should differ accordingly. Hence, even accepting the assumptions made by the theory, the distortions predicted by the principle of primary constancy scaling fail to apply consistently to all aspects of the Müller-Lyer figure.

EXPERIMENT 2

While being relevant to consideration of the mechanism underlying primary constancy scaling, the points raised above omit reference to the appearance of figures from which the paradoxical influence of the two-

dimensional surface, upon which they are drawn, has been removed. This may be achieved by preparing drawings of appropriate figures in luminous paint and viewing them either in after-glow, or in ultra-violet light. Gregory insists that when such figures as the Müller-Lyer and the Necker cube are presented in this way they immediately appear to assume three-dimensional forms, features of which promptly undergo modifications of apparent-size.

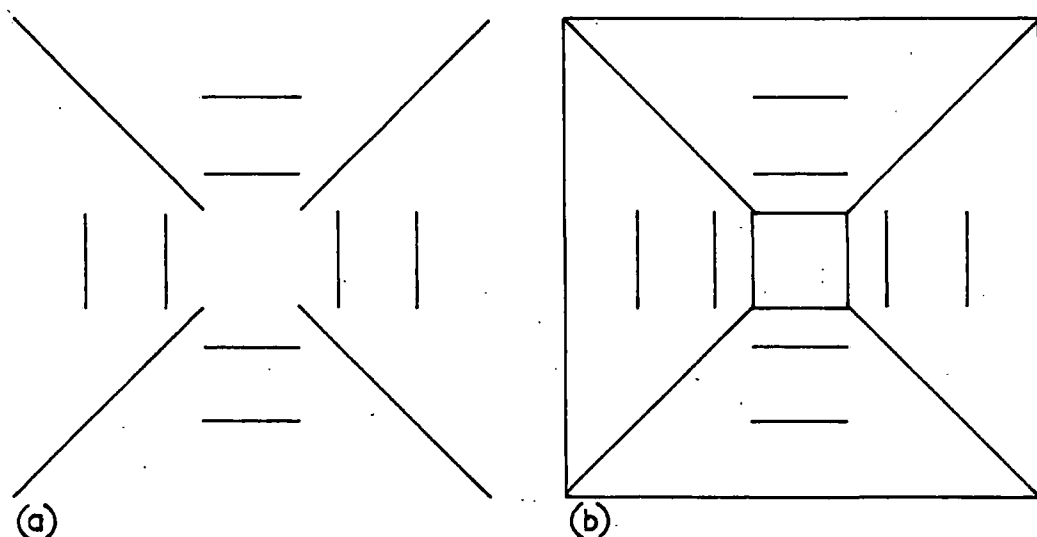


FIG. 4.4 TWO VERSIONS OF THE PONZO ILLUSION

Commenting upon Gregory's version of the constancy theory, Brown and Houssiadas draw attention to the fact that ".... In Ponzo's illusion the same one of the central lines appears longer, no matter whether it is seen as nearer or further away after rotating the figure through 180°" (1964, pp.302-303). Replying to this criticism Gregory refers to the figure reproduced in Fig.

4.4a, observing ".... Brown and Houssiadas argue that the illusion should change with orientation but the perspective is unchanged, and so this is incorrect"

(1964, pp.302-303). This is quite true, the perspective features of the Ponzo illusion are obviously not changed when the figure is rotated, and in each case the inner member of each pair of lines is seen to be longer than the outer. The implication of the reply, nevertheless, appears to be that if the perspective features of this figure were in fact to change, then a reversal in direction of the induced distortion might be expected to appear. Rather surprisingly Gregory fails to realise that the figure to which he refers may, with slight modifications, be transformed into the pattern illustrated in Fig. 4.4b. This figure reverses in aspect readily both when seen as shown here and when observed in reduced-cue conditions. In one aspect it appears to be a side-elevation of a room, the walls of which project forward; in the other it appears to resemble the plan-elevation of a truncated pyramid, the sides of which recede backward.

Further criticism of the constancy theory has been made by Wallace (1966) who points out that, while the perspective features of the Hering (1861) and Orbison (1939) illusions are the same, the characteristic distortions appearing in them are in different directions.

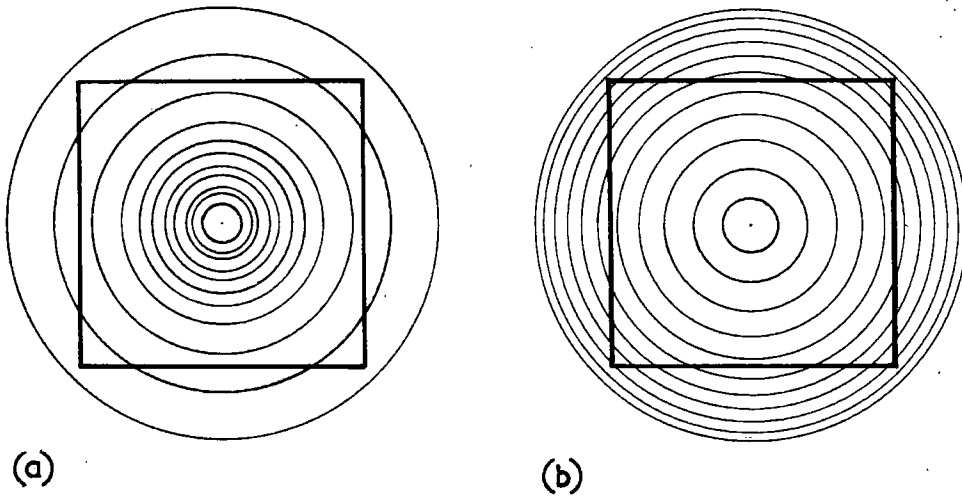


FIG. 4.5 TWO VERSIONS OF THE ORBISON ILLUSION

In the Hering figure the parallel lines bow outwards, while the sides of the square bow inwards in the Orbison figure. In reply Gregory argues that the features of depth induced by the Orbison illusion depend upon the spacing between the concentric circles rather than upon the presence of the circles themselves (1966c). Thus, if the spacing between adjacent circles increases, or decreases, in an appropriate non-uniform way, this figure may be seen either as a tunnel or a cone. Again, Gregory fails to pursue the line of reasoning which he initiates and neither illustrates, nor considers the nature of the illusory distortion which appears in appropriate figures. Drawings of these are shown in Fig. 4.5, a representing a tunnel and Fig. 4.5b a cone.



FIG. 4.6 BUILDINGS UPON FRONT-ELEVATION PHOTOGRAPHS OF WHICH LINES HAVE BEEN SUPERIMPOSED

The architectural features of the buildings shown in Fig. 4.6 are such as to reverse the usual conventions of perspective. In the front-elevation photographs the apex of each roof-line is nearer in space to Q, rather than being further away. Two horizontal lines and two circles have been superimposed upon each of these photographs in such a way as to introduce versions of the Ponzo illusion. If this illusion arises from differential apparent-depth, since, in these photographs, the upper superimposed lines and circles are apparently nearer in space than the lower figures, the ensuing distortion should appear in a direction opposite to that seen in the conventional Ponzo figure.

The principle of secondary constancy scaling makes definitive predictions in relation to each of the displays illustrated in Figs. 4.4, 4.5, and 4.6. In each case, if the theory is valid, apparent-size should be determined by apparent-depth and appropriate distortions should be seen in each figure.

Method and procedure

These drawings and photographs were prepared in two forms; first, as two-dimensional displays as illustrated here; secondly, the figures were drawn in luminous paint and exposed in ultra-violet light in such a way that no

context could be seen. The photographs were prepared as slides and shown by rear-projection in an otherwise dark room in such a way that any paradoxical influence due to context was minimised. All the displays were shown individually to each member of a sample of 50 psychologically naive Os who were instructed to make judgements indicating relevant features of their appearance. These Os were not the same as those who participated in Experiment 1.

Results

The results of these experiments were entirely clear and unequivocal. In summary they were as follows:

- (a) All the Os saw the inner lines in both Fig. 4.4a and 4.4b as being larger than the outer lines. Upon being instructed to do so most of the Os were able to see Fig. 4.4b as having extension in apparent-depth and to reverse in aspect. No differences in the relative apparent-lengths of the inner and outer lines were reported when the figure assumed different aspects.
- (b) All the Os saw both versions of the sides of the square in Fig. 4.5a and 4.5b to be bowed inwards,

that is, in the characteristic direction of the Orbison illusion. Little difficulty was experienced in seeing these figures in three-dimensions and frequently their depth-features were reported to reverse. No attendant changes in the nature of the distortion were observed when this occurred

- (c) All the Qs saw the upper horizontal lines and circles as being larger than the lower ones in all four photographs. Interestingly, some of the Qs were able to see depth-reversals in these photographs also but again no consequent reversals of apparent-size were reported.

In the case of each set of figures studied no differences were apparent between the two conditions of viewing, which were arranged randomly between Qs.

As before, the spatial characteristics of each of the displays used are such as to be amenable to a depth interpretation. If this influences the apparent-sizes and apparent-orientations of lines, appropriate distortions should become evident within these displays. Further, figures may be prepared which either have strong depth features in a given direction, or which reverse in apparent-depth. In either case appropriate distortions should appear according to the principle of secondary

constancy-scaling. None of the distortions predicted by this part of the theory become evident in these figures.

EXPERIMENT 3

The version of the theory under discussion is based upon two 'explanatory' concepts, predictions from which have been considered. Gregory realised, however, that there is no a priori reason why depth features should fix the apparent-positions of stimuli in space uniquely. In the Muller-Lyer figure, for example, it is equally conceivable that each of the shafts should be seen as being in the same depth-plane and that the arrow-heads should appear to project backwards and forwards in the third dimension. If this were the case then presumably no illusory distortion would arise. He appreciates also the difficulties posed for the theory by failure of illusory spatial distortions to undergo modification in figures which represent unusual, or atypical, formal projections and observes that ".... This perspective constancy scaling, then, is not affected by the interpretation of the figure as a whole. It is apparently set systematically by typical perspective depth features, even when non-typical in a given figure. This is seen most clearly in a depth-ambiguous figure, such as the Necker cube, but it

is true also of any perspective figure. For example, the Müller-Lyer arrows can be seen reversed from their typical perspective depth: the illusion remains unchanged when this occurs" (1966a, p.88). Although this argument is advanced in order to forestall criticism of the theory, it is not developed systematically. Nevertheless, it represents the third 'explanatory' principle upon which this version of the constancy theory is based. The concept, if valid, might reasonably be invoked against the arguments developed above, and could conceivably account for such evidence as that of Rivers (1901), Bonte (1962) and Segall, Campbell and Herskovits (1963), all of which appears to indicate that the differential experience of rectilinear plane structures, surfaces and projections of them is instrumental in modifying the nature and extent of illusory spatial distortions.

In developing his account of the constancy theory, Gregory places a good deal of reliance upon the depth features induced by the Müller-Lyer arrows and their influence upon the apparent-depth of the shaft. As is described above, the Müller-Lyer figure is conceived of as being a typical two-dimensional representation of the inner and outer walls of solid structures against which predictable distortions should appear. A difficulty arising from this feature of the theory, however, is that, if

this interpretation is entertained, the two parts of the shaft of the Müller-Lyer figure should be seen at different apparent-depths at one and the same time. While this possibility may be acceptable when considering each part of the figure independently, it is less convincing when applied to the composite figure. The reason for this is simply that the distance of the plane of reference set by the ends of the bisecting arrow-head must be seen as being both nearer to and further from the Q if a consistent three-dimensional interpretation of the form of the figure is to be maintained.

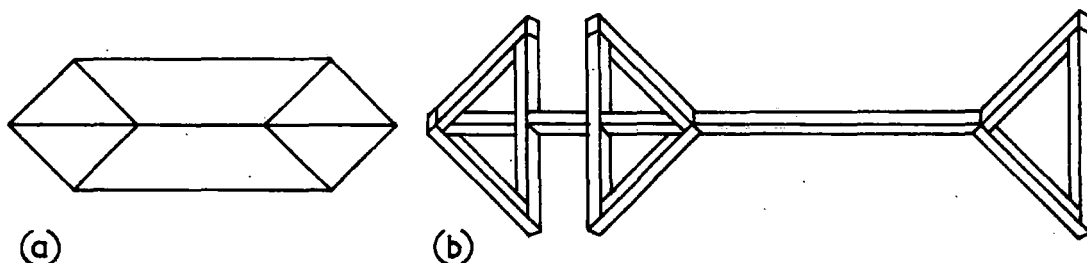


FIG. 4.7 A SKELETON RECTANGULAR FIGURE CONTAINING THE MÜLLER-LYER ILLUSION AND AN 'IMPOSSIBLE' MÜLLER-LYER FIGURE

It may be argued, however, that the Müller-Lyer figure represents part of the edge-on version of the skeleton rectangular figure, illustrated in Fig. 4.7a,

which is seen as extending in apparent-depth. This is true; but this figure will also reverse in aspect readily and parts of the central horizontal line may be associated with either the leading or trailing edges of the figure. Nevertheless, corresponding changes in the apparent-lengths of parts of the shaft fail to appear irrespective of the conditions in which it is observed. Further, the 'impossible' triangular figure illustrated by Gregory (1965) is described by him as containing incompatible information in the third dimension, to which there is no unique solution; hence, the figure cannot be realised as a structural form extending in three-dimensional space. If figures of this kind are added to a straight, horizontal line in such a way as to represent a special version of the Müller-Lyer illusion, the spatial pattern shown in Fig. 4.7b is obtained. As in the case of the conventional Müller-Lyer figure, however, it will be seen that the part of the shaft bracketed by the ingoing angles remains apparently foreshortened in comparison with that bracketed by outgoing angles, irrespective of which interpretation of the figure is entertained.

Diverting as such considerations as these may be, the problem must be faced of exactly what is the nature of a configuration which constitutes a 'typical perspective view'. Implied in the notion of a typical perspec-

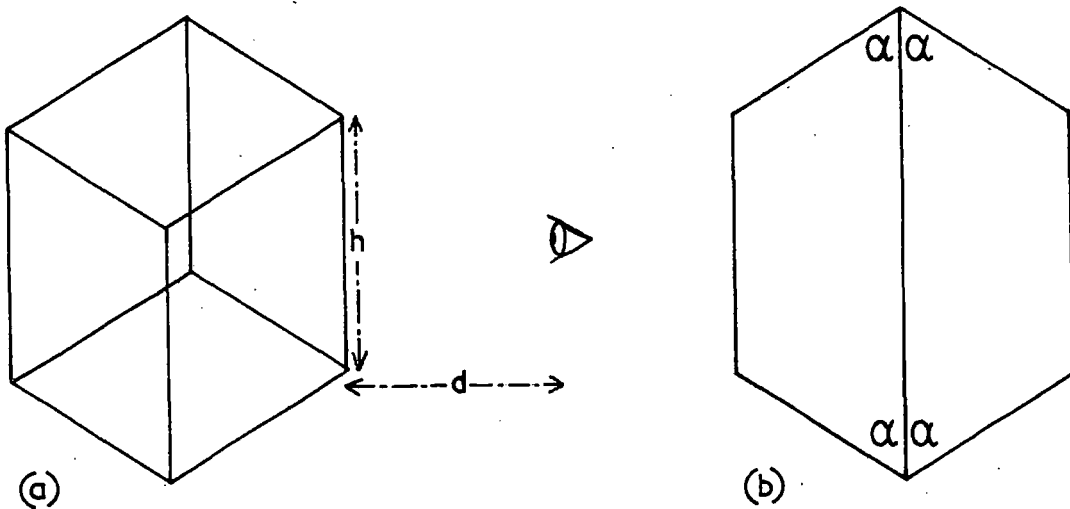


FIG. 4.8 SIDE AND FRONT-ELEVATION OF THE 'TYPICAL PERSPECTIVE VIEW' OF A CUBE-SHAPED STRUCTURE

tive projection of the Müller-Lyer figure, for example, is that the eye is situated at some point upon the horizontal extension of the central part of the edge, or corner, of a rectilinear structure. Side- and front-elevation drawings of such a structure are shown in Fig. 4.8. In Gregory's experiments, designed to observe the relationship between apparent-depth and extent of distortion, the shaft of the Müller-Lyer figure was arranged in such a way as to remain of the same length for each different angle subtended by the bracketing arrow-head. Suppose, however, that the bracketing angles were to remain

the same in a series of figures in which each of the shafts was of a different length. Such figures would represent typical edge-on projections of rectilinear structures, each of which would necessarily appear to be located at a different distance. This distance would be defined uniquely by the spatial characteristics of each display. If the assumption is made that typical three-dimensional structures approximate to the shape of a cube, the location of an Q in relation to the edge of such a structure may be calculated from knowledge of the magnitude of the angle subtended by the lines defining the depth-planes and the height, or length, of the edge.

Method and procedure

According to Gregory, the relationship between apparent-distance and extent of distortion in the Müller-Lyer figure should be linear and positively correlated. His remarkably high correlations between apparent-depth and magnitude of illusion testify strongly to this. The argument invoking typical perspective features implies that this relationship should hold over a wide range. The appropriate prediction has been considered by presenting a specially prepared set of Müller-Lyer figures bracketed by ingoing and outgoing arrow-heads of 60° in re-

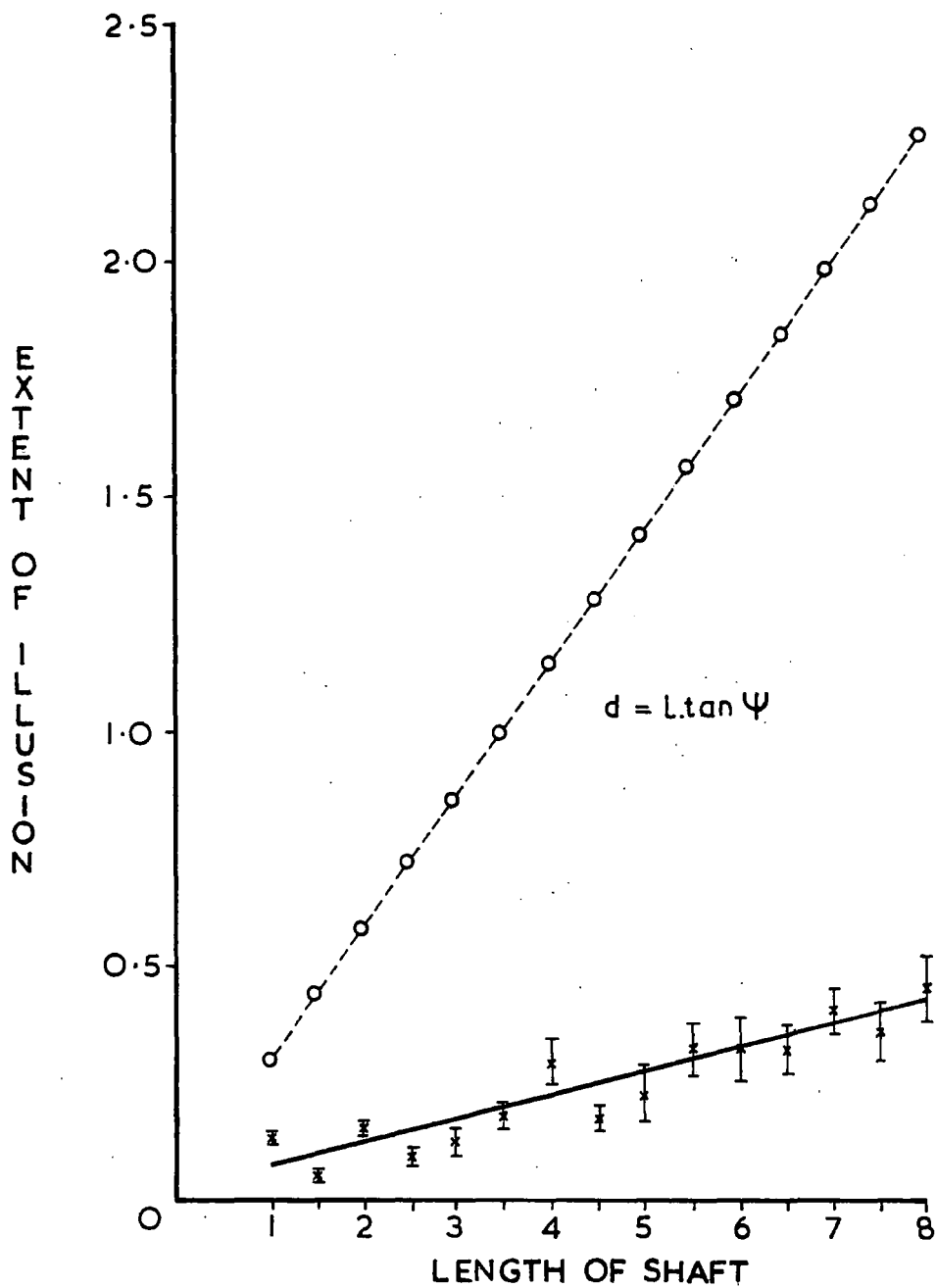


FIG. 4.9 EXTENT OF THE MÜLLER-LYER ILLUSION AGAINST THE LENGTH OF THE SHAFT

uced-cue conditions, the shafts ranging in size from 1 to 8ins. The apparent-lengths of each of these figures were matched with those of unbracketed lines individually by a sample of 100 Os, each of whom made 10 judgments, presentation conditions being randomised in an appropriate way.

Results

For the results of this experiment to be seen most clearly they have been plotted in the graphical form shown in Fig. 4.9. The mean values indicating the extents of the illusion are plotted on the ordinate against the actual length of the shafts which are represented on the abscissa. The vertical bars bounded by short horizontal lines indicate the ranges included by ± 1 standard error about each mean value. The line of best fit to these data is indicated in solid line. This indicates a slight positive acceleration of the function relating the length of the shaft to the extent of the illusion. Considering measures of apparent-depth against the extent of the distortion appearing in this figure, Gregory obtained a correlation of 0.9. If apparent-depth and extent of distortion were related directly, it should be possible to calculate the extent of the distortion appearing in these

figures from knowledge of the nature of the typical perspective view which each represents. By solid trigonometry it may be shown that, if ' ψ ' is the angle subtended by each arm of the bracketing fin with the shaft of the Müller-Lyer figure, and if ' l ' is half the length of the shaft, then ' d ', the distance of the eye of an Q from the edge of an appropriate solid rectilinear structure represented by the figure, is given by the formula:

$$d = l \cdot \tan \psi$$

In the graph this function is plotted in broken line for ' ψ ' of 30° and for a range of ' l ' from 1 - 4ins. In this way the relationship between apparent-location in depth (d) and shaft-length ($2l$) is described. It will be seen clearly that these two functions do not describe a common relationship.

DISCUSSION

Communality of mechanism in the two modes of spatial distortion underlying the geometrical illusions and the perceptual constancies appears to be a somewhat unlikely notion at first sight. Investigations of illusions have usually been undertaken with abstract, two-dimensional spatial patterns, while studies of size-constan-

cy have typically been reserved for concrete, three-dimensional objects. The influence of illusions is to distort the appearance of regular and symmetrical figures, while that of constancy is such as to tend to preserve their regularity and symmetry. In the Orbison illusion, for example, a circle placed upon a pattern of irradiating lines appears to assume an ovoid shape. A penny presented in such a way as to be inclined to the angle of regard appears, however, to be more nearly circular in shape than would be expected from the shape of the image cast by it upon the retina of the eye. Hence, these two effects appear to operate in different directions; since one tends to distort the shape, the other to preserve it. Inappropriate operation of the constancy mechanism, nevertheless, could conceivably be understood to give rise to spatial distortions of the kind usually associated with illusions and this is the fundamental issue raised in the version of the theory under consideration.

The point of departure for this theory is Gregory's dismissal of existing theories intended to explain the appearance of illusory spatial distortions. The arguments which he advances against all but one of these are well-known and require no further elaboration. The theory which merits detailed discussion is that which invokes the principles of perspective to account for illusi-

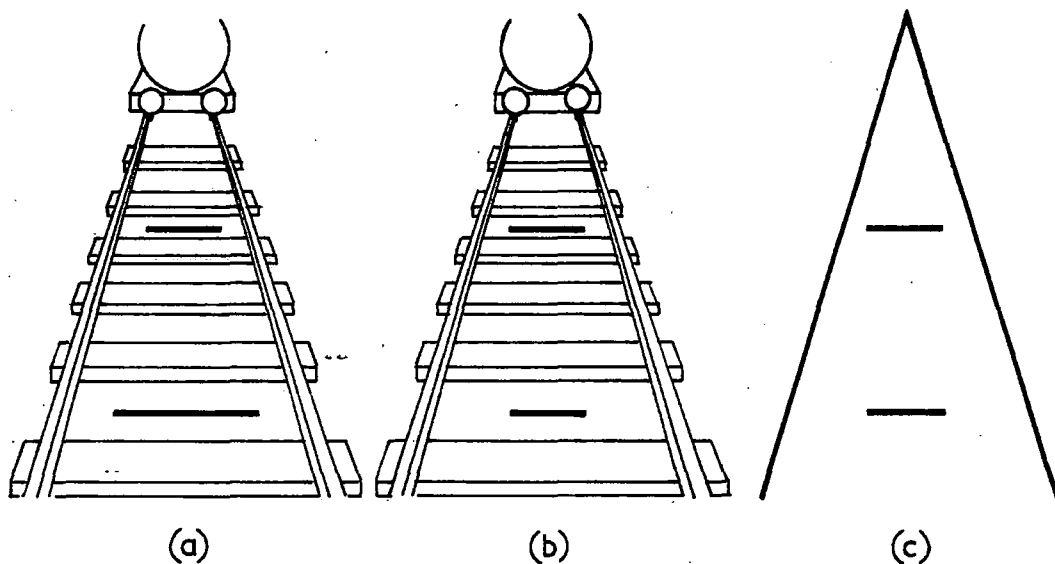


FIG. 4.10 RAILWAY LINES AND THE PONZO ILLUSION

ons. This goes back at least to 1896 when Thiéry observed that a number of illusion-figures resembled two-dimensional projections of objects extending into three-dimensional space. The Müller-Lyer figure, for example, reminded him of the legs and cross-member of a saw-horse. Subsequently, the relevance of perspective to illusions was described by Woodworth (1938). The perspective features of the drawing of the railway-track, illustrated in Fig. 4.10a, are also such that it appears to extend into three-dimensional space. The converging lines representing the track appear to recede into the distance and the lower horizontal line drawn between the sleepers

is apparently nearer in three-dimensional space than the upper line. In Fig. 4.10a the conventions of perspective have been observed, the lower line being actually longer than the upper line. Hence, the two horizontal lines appear to be both of the same size while being apparently located at different distances. In Fig. 4.10b, while appearing to remain at different distances, the two horizontal lines are of the same physical length. This will be seen, therefore, to bear a close resemblance to the version of the Ponzo illusion illustrated in Fig. 4.10c, the distortion characteristic of which appears in both figures.

The Ponzo illusion should be considered carefully, particularly when attempting to invoke perspective features by way of explanation of the typical nature of the particular spatial distortion which appears within it. According to the principles of perspective, an inverse relationship should hold between the size of an object and the distance at which it appears to be placed. Hence, an object, or spatial pattern, which appears to be nearer should appear larger than one which is apparently situated further away. Accordingly, it seems that any distortion induced by perspective features should be in the direction of increasing the apparent-size of the lower line of the Ponzo illusion. Typically, however, the upper line is the one which appears to be longer. Greg-

ory draws attention to the characteristic distortion evident in this figure, in his rejection of the perspective theory observing ".... why should suggestion of greater distance produce increase in size when distant objects are typically seen as smaller with increasing distance? The theory predicts not an increase, but a decrease in the size of features having greater distance indicated by perspective but this is the wrong way round" (1966b, p.147). He reaffirms this view in observing ".... From this point the perspective theory goes off the rails. It states that depth is 'suggested' by the perspective features, and this 'suggestion' produces an expansion of the more distant features. But even if we allowed that a 'suggestion' could cause a size change, it would be the wrong way round because distant objects in the real world look smaller not larger. In each case the traditional perspective theory gives exactly the wrong prediction" (1966a, p.78)

At first sight this argument appears to be extremely convincing and, if it is tenable, it clearly implies that the perspective theory as such must be rejected. Accepting that the tendency to see illusory-patterns as two-dimensional representations of three-dimensional figures could induce distortions due to confusion in inter-relating the apparent-sizes of lines and shapes with the distances at which they appear to be located, the nature

of any such distortions should be predictable. In the Ponzo figure two lines, actually equal in length, appear to be placed at different distances, they also appear to differ in length. The line which appears to be further away, however, is apparently enlarged rather than foreshortened. Accordingly, it seems that the relationship between apparent-size and apparent-distance must necessarily confound the argument from perspective.

The lines contained within the angles of the Ponzo figure are, however, of the same length. They are not objects casting images of different sizes upon the retina, the assumption implied in all versions of the constancy theory, but give rise to retinal projections of the same size. Since image-size is controlled, the principle relating apparent-size to apparent-distance is that embodied in Emmert's law which refers not only to after-images but to any magnitude-estimation in which the size of the retinal image is equated. Gregory denies that Emmert's law is relevant to illusory-figures presented in the form of two-dimensional drawings, the surfaces of which are defined clearly, but this derives from confusion as to the relevance and implications of Emmert's law, from which an explanation of the characteristic appearance of the Ponzo figure follows.

Nor does the argument preclude an explanation in terms of perspective. In the Ponzo illusion two lines are

present and they are seen together. The task of Os faced with the figure is that of making a comparative judgment of the length of one line with respect to that of the other. Suppose, however, that one is asked not to judge the relative apparent-sizes of the two lines but to draw-in an upper line, say, which appears to be of the same length as the lower line in an appropriate incomplete Ponzo figure. The line so drawn will undoubtedly be shorter than the lower line. It will thus resemble the form shown in Fig. 4.10a. The upper line which appears in the complete version of the Ponzo figure is longer than the line which would be produced by construction and, not unnaturally, it appears to be so. Accordingly, the arguments against both the relevance of Emmert's law and the principles of perspective appear to be entirely unconvincing.

The experiment which reveals exceptionally high correlations between the extent of the distortion in the Müller-Lyer figure and its location in apparent-depth, on the other hand, appears to be extremely convincing. If this figure is interpreted as being a two-dimensional projection of the edge of a symmetrical rectilinear structure, it is conceivable that such a projection might appear to undergo apparent-distortion. The spatial characteristics of a given Müller-Lyer figure are such, however, as to define uniquely the form which an appropriate

three-dimensional structure must take. The function relating angle of bracket and length of shaft with appropriate apparent-distance, described earlier, is such as to render a direct relationship between extent of distortion and apparent-distance highly questionable. In laboratory demonstrations of the Müller-Lyer illusion it is customary to prepare a figure having a shaft length of 2 or 3 ins. For such figures to be seen as typical perspective projections of solid figures the eye would have to appear to be placed at a distance of less than one inch from the edge, for a bracketing angle of 60° . An interpretation of this kind seems to be extremely unlikely. Further, it is doubtful if Gregory's experiment on the Müller-Lyer illusion even succeeds in establishing the relationship which it was designed to consider. The logic of the argument relates the extent of the illusion to the angle of the arrow-head which is in turn related to apparent-depth. Nevertheless, irrespective of any influence due to constancy a line or figure which appears shorter also appears to be closer and one which appears longer appears to be further away. This again being the principle implied in Emmert's law. A line bounded by outward flaring arrow-heads appears to be considerably longer than one bounded by inward flaring arrows. Clearly, it is to be expected that lines differing in apparent-length should also appear to differ corr-

espondingly in apparent-distance. But this is irrelevant to explanation of the nature of any differences in their apparent-lengths. This experiment thus fails to establish the relationship under consideration, rather, it capitalises upon the nature of the Müller-Lyer figure as seen. Hence, instead of demonstrating an important principle relating apparent-depth and extent of illusory distortion, it provides a novel demonstration of Emmert's law.

CONCLUSIONS

The constancy theory has been discussed in some detail since it has the quality of being an essentially psychological theory which attempts to link hitherto unexplained phenomena with well-established facts concerned with other known aspects of perceptual organisation. As such it is an excellent paradigm for psychological theorising. The need for postulation of principles other than those implied in Emmert's law and in perspective interpretations of two-dimensional figures has been considered. Predictions made from the two 'explanatory' concepts and the rider embodied in the constancy theory have been tested experimentally. The outcome of these considerations is such that we are reluctantly forced to the

conclusion that constancy cannot reasonably be brought to account as the mechanism underlying the distortions seen in the geometrical illusions.

CHAPTER 5

AN EXPERIMENTAL AND THEORETICAL APPRAISAL OF THE INAPPROPRIATE SIZE-DEPTH THEORIES OF ILLUSIONS

Many theories have been formulated in the attempt to explain the appearance of illusory distortion in two-dimensional spatial patterns. The most persuasive of these are based upon the consequences of the differential features which certain examples of such patterns might be interpreted as having. Thiéry (1896) noted the resemblances of some geometrical illusions to two-dimensional projections of three-dimensional scenes and structures. He drew particular attention to the Müller-Lyer (1889) illusion which reminded him of the cross-member and trestle-legs of a saw-bench. The possibility of depth being inferred when configurations of this kind are observed and of such inferences being responsible for modifying the apparent-lengths, -sizes and -shapes of some spatial patterns was developed in Thiéry's first systematic account of 'the perspective theory' of illusions.

Closely related to the argument from perspective is the hypothesis of 'the carpentered world' which was proposed by Segall, Campbell and Herskovits (1963, 1966) and developed from the early cross-cultural studies of Rivers (1901, 1905). The causal properties of the mech-

anisms invoked by both the perspective and the carpentered environment theories are essentially similar. Hitherto, however, the possible ways in which any depth features implicit in two-dimensional patterns are understood to modify their appearances have been stated in general terms only. At the outset it should be emphasised that the perceptual mechanism implied in all theories of this kind is considered as operating in two stages. First, the contours composing certain two-dimensional configurations are interpreted as giving the impression of depth; thus, in the Ponzo (1912) illusion, for example, convergence of the oblique lines serves to indicate increasing distance. Secondly, the sizes of any additional contours superimposed upon such patterns are judged in accordance with the distances at which they appear to be located. It follows that, when distance is judged incorrectly in a flat figure embodying converging contours, a commensurate error should be made in the judgment of size. Accordingly, features of such a figure appear distorted, an illusion becoming apparent. Thus, explanations of illusory distortion expressed in terms of this two-stage process proceed to apparent-size via apparent-distance. Hence, they may be referred to as 'inappropriate size-depth theories'. The purpose of this chapter is to make a detailed evaluation of theories of this kind.

EXPERIMENT 1

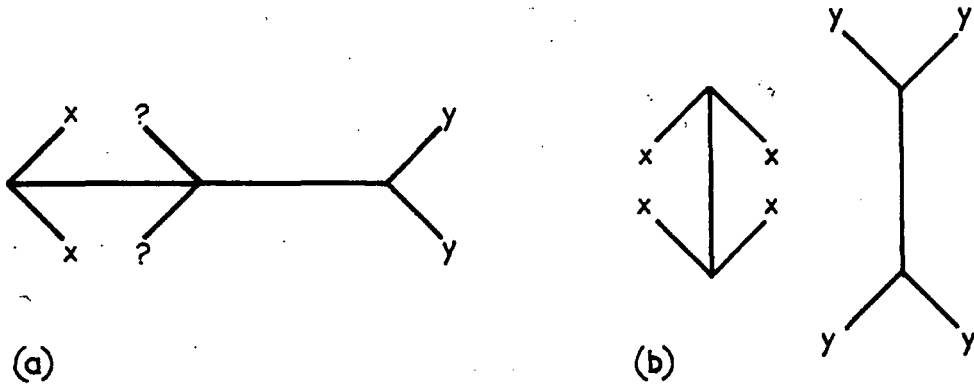


FIG. 5.1 THE MÜLLER-LYER ILLUSION IN (a) COMPOSITE AND (b) COMPONENT FORM

The illusory pattern to which more research has been devoted than any other was first described by Müller-Lyer. In this illusion a straight shaft, bounded and bisected by arrow-heads, as in Fig. 5.1a, undergoes distortion in such a way that its two halves appear to be unequal. The forms apparently assumed by the two components of the Müller-Lyer figure, shown in Fig. 5.1b, are such as to lend themselves readily to an explanation expressed in terms of perspective. Many suggestions have been made as to how this particular illusion might be accounted for in accordance with apparent-depth. For convenience, both in measuring the magnitude of the apparent-distortion and in maintaining the consistency of

the argument, all such suggestions have made reference to the two individual elements of the illusion. In general, proposals of this kind imply that the ends of the arrow-heads bounding the vertical lines are instrumental in setting the reference planes for distance against which the remaining features of the figures are seen.

Tausch (1954) also noted the resemblance of such patterns as those defining the Ponzo and Müller-Lyer illusions to three-dimensional forms and Gregory (1963, 1966a) proposed specifically that the shaft bounded by inward-flaring arrow-heads in the latter represents a 'typical perspective view' of the outer edge of a building, while that with outward-flaring arrows is strongly reminiscent of the inner corner of a room. Should typically occurring perspective features of the spatial environment be instrumental in modifying the appearances of two-dimensional forms, a consistent explanation of the distortions seen in the two parts of the Müller-Lyer figure might follow. If this were the case, the ends of the arrow-heads marked 'X' in Fig. 5.1b would be interpreted by an observer as being further away in space than the vertical shaft, while those indicated by the letter 'Y' would seem closer. According to Emmert's law (1881), the line bounded by ingoing arrow-heads should appear shorter than that bounded by outgoing arrow-heads. This characterises the nature and direction of the dis-

tortions usually apparent in these two figures.

It is unfortunate, however, that while being extremely plausible this argument remains incomplete. Having developed an explanation for the different distortions apparent in the two components of the Müller-Lyer figure it should be a straightforward matter to extend the same explanation, if it is valid, to the composite form of the illusion. While this may have been attempted by those engaged in studying this illusion a convincing account has never been advanced to explain the composite illusion in accordance with any differential depth features which it might have. The reason for this omission is not difficult to determine. The arrow-heads bounding Fig. 5.1a could conceivably be interpreted as fixing the depth planes of the ends of the two halves of the shaft, as is indicated by inclusion of the letters 'X' and 'Y', following the convention employed in Fig. 5.1b. But what depth interpretation could possibly be placed upon the arrow-head which bisects the figure? To maintain a consistent explanation of the form assumed by the complete Müller-Lyer illusion the ends of this arrow must be seen as being both in front of and behind the shaft if the distortion is to be understood in accordance with differential apparent-depth. Thus, when understood in these terms, the shaft of the figure must be seen as being bo-

th nearer to and further from an observer simultaneously. A depth interpretation of this kind seems extremely unlikely.

Method

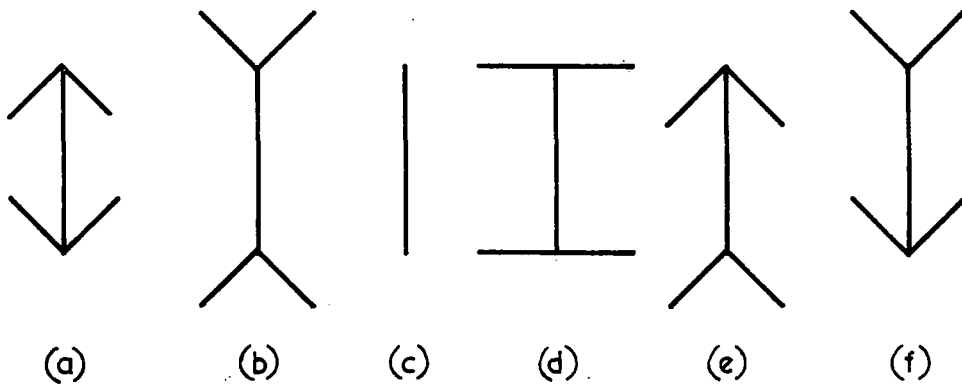


FIG. 5.2 THE SIX FORMS STUDIED EXPERIMENTALLY

The principal reason why the Müller-Lyer illusion has been employed so widely, particularly by those anxious to develop the various versions of inappropriate size-depth theories, is that the addition of arrow-heads to straight lines serves to yield a convincing depth impression of the overall forms of such patterns as are illustrated in Figs. 5.2a and b. It is customary to measure the apparent-lengths of such figures in some convenient way and to compare them with appropriate control pat-

terns of the kind shown in Figs. 5.2g and d. Equally, if not more, convincing depth features may be introduced into the appearance of straight lines, however, by adding arrow-heads to either of their ends, both of which point in the same direction, this being illustrated in Figs. 5.2e and 5.2f. If the argument from depth is valid then the apparent-lengths of these figures should vary in accordance with the apparent-locations of their shafts.

Apparatus

Procedurally the problem was that of determining the magnitude of any distortion apparent in each of the six patterns illustrated in Fig. 5.2. This was achieved by devising a 'slide-rule' technique using which the six figures were etched in black line upon sheets of a dense matt-white plastic material, the overall surface dimensions of each being 45cm. x 10cm. The shafts of all the figures were 100mm. long, the additional components were formed by lines 25mm. long and all contours were 2mm. in width. A further unbounded line, 150mm. in length, was placed in the same plane as each pattern, the adjacent ends of the shaft and the line being separated by a distance of 30mm. Channels were attached to the longer edge

of each surface so that a slider could be fitted in such a way as to move across the display, thus obscuring part of the longer unbracketed line. A machine-divided vernier scale fitted to the back of each slide-rule enabled the relative positions of the stimulus-displays and the sliders to be determined with an accuracy of $\pm 0.1\text{mm}$.

Procedure

Arranged upon each occasion in a different random order the six displays were presented to subjects who were required to adjust the slider so that the shaft of the figure and the comparison line appeared equal in length. All subjects made four judgments of each display, initial positions of the sliders and left-right orientation of the shafts and comparison lines being randomised appropriately. The slide-rules were placed in such positions that their display surfaces were orthogonal with subjects' line of regard at a distance of 50cm. from the eyes.

Instructions

The verbal instructions given to subjects were as follows:

'I am interested to learn how well you are able to judge the length of one horizontal line with respect to another. Here is one such pair (standard feature of display indicated), will you kindly adjust this slider (also indicated), so that both the horizontal lines appear to be identical in length?

Subjects

One hundred subjects participated in this experiment. Twenty-three of their number were University students whose ages ranged from 20 to 27 years, fourteen members being female. The remaining subjects were sampled essentially at random from the populace of the City of Newcastle upon Tyne. They were members of a panel of people formed with the intention of ensuring that those participating in a long-term series of studies of a variety of perceptual phenomena should be reasonably representative of the populace at large. These subjects ranged in age from 17 to 64 years, forty-three members being female.

Subjects were included in the sample notwithstanding any visual defects they might have had. While it might be worthy of note that eight members of the sample wore spectacles whilst engaged in the experiment, their judg-

ments proved in no way atypical. The degree of psychological sophistication of the subjects differed widely. Thirty members of the experimental sample, all the students and some of the panel, were familiar with perceptual phenomena of the kind under consideration. Since it is well-known that, in certain circumstances, prior experience of illusory distortions serves to modify their extents, this was unfortunate but unavoidable. Data referring to 'experienced' and 'inexperienced' groups were compared, however, and they failed to be distinguished statistically.

Results

TABLE 5.1

THE APPARENT-LENGTHS OF THE EXPERIMENTAL
STIMULUS PATTERNS

Display :	(a)	(b)	(c)	(d)	(e)	(f)*
\bar{X} :	88.52	115.52	100.32	97.72	102.44	101.84
$\delta\bar{x}$:	1.46	1.17	1.18	1.16	1.24	1.42

The results of this experiment are entered in Table 5.1. The shafts included in each of the experimental stimulus patterns were all 100mm. long. Numerical values, expressed in units of mm., indicating the lengths of the lines with which the shafts were equated are given for all six displays. The mean values (\bar{X}) refer to the combined judgments of the total sample of subjects. The standard errors of estimate ($\delta\bar{X}$) associated with these values are included also. The results show clearly that the typical Müller-Lyer distortions appear in Figs. 5.2a and b. They confirm the hitherto unexplained observation of Binet (1895) that the elongating influence of the outgoing arrows exceeds that of the foreshortening influence of the ingoing arrows. No significant distortion appears in Fig. c. A slight degree of foreshortening appears in Fig. 5.2d and some small elongation is evident in both Figs. 5.2e and f.

Of greatest importance for present considerations are the apparent-lengths assumed by the latter two patterns. Slight distortions appear in them both, - but they are both in the same direction and they are not distinguished in a statistical sense. The perspective elements in Figs. 5.2e and f are as equally strongly defined as any such features implicit in the forms of Figs. 5.2a and b. Accordingly, on the basis of these results, it seems reasonable to draw the conclusion that apparent-differen-

tial depth as such cannot be held responsible for the spatial distortions evident in the Müller-Lyer illusion.

EXPERIMENT 2

The argument developed in the previous experiment rested upon the depth features being maintained when replacing the conventional Müller-Lyer arrow-heads by others, both of which face in the same, rather than in opposite, directions. In passing, it might be noted that these patterns provide more appropriate control situations for evaluation of this illusion than have formerly been employed.

Figs. 5.1a and b show that specification of the features of two-dimensional spatial patterns which appear to have different depth locations has proceeded in a convenient but essentially post hoc way. It is by no means axiomatic that the ends of the arrow-heads labelled 'X' in Fig. 5.1 should be interpreted as being located at a further distance than the shaft, nor that those marked 'Y' should appear to be closer. Other interpretations are equally possible, even accepting the notion of certain configurations being interpreted as representing

projections of typical structural features of Western environments. If the ends of the shafts were to be seen in such a way as to fix the depth-references of the figures the barbs would appear to recede backwards and to project forwards respectively, but if this interpretation were to be appealed to it is difficult to see how any illusory distortions could become apparent. Further, the forms of these figures could be interpreted in a way diametrically opposite to that usually taken of them by inappropriate-depth theories since it is not difficult to see the relative positions of 'X' and 'Y' as being reversed; - that is to say, 'X' being in a position in advance of the shaft and 'Y' behind it. In fact, the two components of the Müller-Lyer figure alternate readily in apparent-depth, but the reversal in direction of the illusion which might be expected to arise when this occurs does not appear.

The depth features of Figs. 5.2e and f also alternate and it is a relatively simple matter for subjects to 'hold' them in either of their two mutually exclusive aspects. The purpose of the second experiment was to determine whether or not differential distortion arises as a consequence of the two opposed depth aspects in which these patterns may be seen.

Method and Procedure

The operational details only of this study need to be specified. The sample of subjects was the same as participated previously, the four slide-rules displaying the patterns illustrated in Figs. 5.2a, b, e and f were used again. The procedures adopted and judgments required were the same as before except in the following details.

Some degree of sophistication was required of subjects making the judgments in this experiment since it was necessary for them to attempt to see the stimulus-displays in different depth forms and to maintain them in a given aspect whilst considering their apparent-lengths. To facilitate these requirements, a drawing of the skeleton cube-shaped form first described by Necker (1832) was included in the letter with which an appointment was made with each subject. Along with this was a note describing the appearance of the figure in depth and a request to inspect it periodically before visiting the laboratory. Particular reference was made to the two different depth interpretations of the Necker cube and to the need for attempting to maintain it in either depth aspect for periods of half a minute or so. Thus, when carrying out the experimental procedures all subjects were familiar with the requirements.

Instructions

All subjects were instructed verbally as follows:
'You recall how you were able to see the skeleton cube in either of two depth forms and how you found it possible to maintain it for a period of time in one or other of its aspects? These patterns can be seen in a similar way. In each case I will indicate that I wish you to 'hold' the position of the shaft of the figure either forward, or behind the oblique lines. Thus, the ends of the arrow-heads should appear to recede backwards, or to project forwards from the shafts. When you are satisfied that you are able to see the figure in the required way kindly adjust the length of the comparison line so as to equate it with that of the shaft. Please be careful to ensure that the appearance of each figure is maintained throughout the period during which you make any adjustments. Should it appear to reverse in depth just look away from the apparatus momentarily and then repeat the procedure'

Results

TABLE 5.11

THE APPARENT-LENGTHS OF THE FOUR STIMULUS PATTERNS
MAINTAINED IN BOTH DEPTH ASPECTS

Display :	(a)		(b)		(e)		(f)*	
Shaft held :	Forward	Backward	Forward	Backward	Forward	Backward	Forward	Backward
\bar{X} :	91.60	93.20	114.40	113.20	105.20	105.60	104.40	106.80
$\delta\bar{x}$:	1.40	1.68	1.54	1.36	2.32	2.58	2.48	2.40
t :	0.73		0.59		0.12		0.70	
p :	>0.05		>0.05		>0.05		>0.05	

The results are entered in Table 5.11 using the same conventions as were employed previously. Judgments made in relation to the two alternative depth locations of each shaft are referred to according to whether it was maintained in an apparent-position in front of, or behind, the obliques. As before the typical Müller-Lyer distortions are evident in Figs. 5.2a and b and again slight elongations appear in Figs. 5.2e and f. The values of Student's statistic 't' relevant to consideration of whether, or not, each of the comparable sets of judg-

ments may be considered to have been drawn from the same population of responses are entered in the table. Beneath these are given estimates of the probabilities of occurrence of the differences on the appropriate null-hypothesis. It is clear that the response parameters under consideration fail to be distinguished significantly in a statistical sense. Hence, these results appear to confirm the conclusion that the perspective features indicated by the oblique contours fail to be responsible for inducing the illusory distortions seen in the Müller-Lyer figure.

DISCUSSION

The problems posed by failure of certain stimulus configurations to conform perceptually with their physical dimensions are simple to state, albeit difficult to solve. In the everyday behaviour of human beings the special senses and the perceptual scaling mechanisms with which they are associated operate so as to afford a highly veridical account of the physical environment. Certain of the transducer functions of the sensory end-organs are reserved for extrapolation of information indicating the dimensions of features of the spatial world and those of the perceptual systems are concerned with

performing an analysis of it. Naturally, a characteristic degree of error is involved in each of the operational components of the spatial senses. Nevertheless, the development of high degrees of sensori-motor skill and the accuracy with which spatial judgments can be made shows that, in general, perceptual computation of spatial dimensions is extremely reliable. When required to process the information in certain displays, however, remarkable distortions become evident; straight lines appear appreciably curved, regular forms are grossly misshapen and identical shapes seem markedly different. Thus, the information-extrapolating and -processing systems which allow relatively accurate judgments to be made of the forms of some spatial patterns fail to do so when faced with others.

Since Oppel (1855) first drew attention to the 'geometrical optical illusions' many attempts have been made to explain their phenomenal attributes in terms of the structural organisation and functional repertoire of the spatial senses. The names of those who have become involved in studying illusory distortions testify strongly to the importance placed upon developing an acceptable theoretical account of them. The arguments advanced against the majority of proposed theories are well-known and require no further elaboration. The theories which do merit detailed discussion are those which understand illusi-

ons to arise in some way as a consequence of breakdown in the perceptual analysis of size in accordance with distance. The 'face-validity' of theories of this kind is such that, in one form or another, they have become very widely held by experimental psychologists. Accordingly, it is timely that their basic postulates, their implications and their validity should be brought into question.

The principles upon which the perspective theory is founded are fundamental to all formulations of inappropriate size-depth explanations. It rests upon the simple and persuasive assumption that the sensory systems and perceptual mechanisms responsible for performing an analysis of three-dimensional space continue to operate when presented with two-dimensional patterns. Certain examples of such patterns resemble front-, plan- and side-elevation projections of three-dimensional scenes and solid structures. In three dimensions parts of such scenes and structures are located at different distances from the eye of an observer. Accordingly, if distance is inferred in a two-dimensional pattern and, if size should be determined commensurately, an illusion must arise.

Hitherto, the only serious objection raised against the perspective theory was advanced by Gregory who argued very convincingly that, while apparent-distance is undoub-

tedly relevant to explanation of illusory distortions, the principles of perspective generate certain erroneous predictions. He illustrated these by reference to the distortion which characterises the Ponzo (1912) illusion, in which the upper member of a pair of identical horizontal lines, bounded by converging contours, appears longer than the lower. Gregory suggested that, if this figure were to be seen as the perspective projection of a scene receding into the distance, the upper line should appear shorter than the lower. In Chapter 4 this proposal has been disputed, however, the argument being that the distortion evidenced in the Ponzo figure is in no way at variance with any depth features which might be implicit in it.

Implied in the perspective theory, however, is a logical corollary which should be noted. The characteristic functional modes of the mechanisms which allow three-dimensional space to be judged accurately are inappropriate for processing the information in two-dimensional configurations. It follows that veridical perception of three-dimensional space is achieved at the cost of illusory distortion of two-dimensional space. Hence, this argument implies that the appearance of illusions should be confined to two-dimensional patterns and that they should not arise when viewing three-dimensional scenes. This theme was developed by Piéron (1955) who emph-

asised the view that illusory distortions disappear completely when the contours in which they arise are given strongly defined depth connotations. In the course of his attempt to relegate the study of illusions to perceptual curiosities, having little relevance to the broader problems of visual perception, Piéron observed that ".. if the two segments (of the oblique components of the Poggendorff (1860) illusion) are made of rope passing behind a column and serving to pull a bucket out of a well, the illusion disappears completely. Consequently, I believe that one must not exaggerate the importance of optical illusions. I repeat, they have little connection with everyday life (op.cit. p.76). He extended this argument to consideration of the Müller-Lyer illusion which he claimed likewise fails to arise when it is embodied within a concrete context, stating "....The Müller-Lyer illusion is a phenomenon which never has any influence upon our spatial activity. It is a curiosity the principle upon which the illusion is based is of no spatial importance" (op.cit. pp.75-76)

Piéron's observations, and others carrying similar implications, are of direct relevance to the explanatory nature of the perspective theory since they seek to capitalise upon the consequences of its basic assumption. Empirical evidence for failure of illusions to persist in three-dimensional contexts was obtained in the experi-

mental studies of Filehne (1898) and Ebbinghaus (1902). These studies have been repeated by Fisher and Lucas (1968) and by Lucas and Fisher (1968) who demonstrated that illusions remain, unchanged in direction and undiminished in extent, when the contours which define them form parts of three-dimensional scenes and when they are embodied within meaningful two-dimensional spatial patterns. Accordingly, it seems unreasonable to pursue the claim that illusory distortion of two-dimensional space is a necessary consequence of reliable perception of three-dimensional space.

Since the causal construct of 'the carpentered world hypothesis' is essentially the same as that of the perspective theory, the above considerations are equally relevant to the view that familiarity of typical scenes and structures serves to develop visual habits of inference having appropriate ecological validity. Rivers and Segall et al. showed that those living in different cultures differed in their susceptibility to illusory distortions. In Chapter 3 the argument from the characteristic rectilinear nature of Western environments was questioned, however, in demonstrating that illusions continue to appear when the distorting elements of a number of well-known illusions are replaced by curvilinear contours. It can scarcely be denied that the ecologies of the societies studied by those who have attempted to delineate

the cultural determinants of space perception contain many curved natural forms and a variety of circular artefacts. It should be noted that no dispute arises over whether, or not, illusions arise with different orders of magnitude in those domiciled in different environments, they almost certainly do. What is being brought into question is why this should be the case, and specifically under consideration is whether, or not, they arise as a consequence of the different depth interpretations which might be placed upon two-dimensional spatial patterns. In common with other inappropriate size-depth theories, the hypothesis of the carpentered world appeals to the view that if depth is inferred then illusions must arise as a consequence. It is clear that neither the present experiments nor the previous studies referred to above can be interpreted as supporting such a view.

The points raised in the preceding discussion and the results of the experiments reported in this chapter are of direct relevance also to the contemporary theory of illusions based upon the inappropriate operation of the mechanism underlying size-constancy. A detailed evaluation of this theory has been developed in Chapter 4. A large part of the support for the notion of size-constancy playing a role in inducing illusory spatial distortions rests upon a study reported by Gregory (1966a) in which remarkably high correlations were observed

between the apparent-lengths of the shafts of the two elements of the Müller-Lyer figure and their apparent-locations in depth; - that is to say, the magnitude of the illusion was found to vary as a function of apparent-distance. From this study Gregory concluded "... The extent of the illusion follows the amount of recorded depth very closely, for both directions. We may regard this result as strong evidence for relating the illusion to perspective depth...." (p.95)

Had patterns of the kind illustrated in Figs. 5.2e and f been introduced into Gregory's study it would certainly have proved possible to see them in accordance with their two depth aspects. But their failure to exhibit different degrees of distortion would have made for difficulties in drawing a conclusion of this kind. Nevertheless, illusory distortions do appear in the conventional components of the Müller-Lyer figure itself; hence, Gregory's account and interpretation of them should be discussed.

Lines bounded by arrow-heads, such as are shown in Figs. 5.2a and b, appear to differ in length, the former seeming somewhat shorter than the latter. Irrespective of any size-differences arising as a consequence of the operation of the constancy mechanism, however, a line which appears shorter also seems to be closer in space than one which appears longer. This phenomenon is clear-

ly evident, notwithstanding the fact that the retinal images arising from the presence of the two lines are identical in size. The logic of such situations was discussed by Emmert (1881) and the relationship between apparent-size and apparent-distance is expressed in the Law which bears his name. A line bounded by outward-flaring obliques appears to be considerably longer than an otherwise similar line bracketed by inward-flaring obliques. Naturally, it is to be expected that contours which differ in apparent-length should also appear to differ correspondingly in apparent-distance. But such differences in apparent-distance are clearly irrelevant to explanation of differences in apparent-size,- that is to say, they do not explain why the two lines should appear to assume different lengths in the first place. Thus, the experiment designed with the intention of demonstrating the postulated relationship exploits the nature of the two parts of the Müller-Lyer illusion as seen rather than confirming that a further mechanism is responsible for the distortions evident in them.

As pointed out in introducing the topic of this chapter all inappropriate size-depth theories appeal to a two-stage perceptual process according to which depth is first determined whereupon size is judged accordingly. Innumerable experimental studies of space perception have shown that the size of stimulus can be interpreted from its app-

arent-distance and, conversely, that distance may be determined in accordance with its apparent-size. These experiments have served to reinforce the persuasive view that an acceptable explanation of illusory distortion is to be sought in terms of inappropriate perceptual computation of size and distance. The question which remains, however, refers to whether the distance indicated by such contours as the obliques incorporated in the Müller-Lyer figure, or the presence of these contours themselves, is responsible for the distortions seen in the shafts. The results of the present experiments cast strong doubt upon the former view since differential apparent-size failed to arise as a consequence of variation in apparent-distance. Accordingly, it is concluded that the validity of the inappropriate size-depth theories is questionable.

CHAPTER 6

CONCLUSIONS

The emphasis throughout this work has been placed squarely upon consideration of the empiricistic nature of certain theories concerned with the development of features of perceptual organisation. All the theories discussed imply that the experience afforded to human beings by the spatial contours, forms and structures which constitute typical features of their physical environments are instrumental in modifying the ways in which they are perceived.

'The perspective theory' is the forerunner of all formulations of this kind. It involves the assumption that depth is inferred in two-dimensional patterns and that, when such inferences prove to be inappropriate, a spatial distortion will become apparent. While it is not made explicit in original statements of this theory, consideration of the perspective features of spatial patterns being responsible for the apparent-distortions seen in them raises the question of the level at which any learning might take place. There are two possibilities. First, the learned element could arise at the stage of seeing a spatial pattern in the third dimension

initially. Secondly, having seen the pattern in depth, any learning involved might manifest itself in the subsequent inference made in inter-relating distance with size.

The specific contribution of 'the carpentered world hypothesis' is that it attempts to distinguish between these two possibilities. It suggests that the spatial patterns characteristic of different cultural ecologies come to have differential cue validity in the course of experience of them. Thus, the implication is that any learning involved arises at the second of the two stages described above. Notwithstanding the arguments developed in Chapter 3 of this work, the internal consistency and ramifications of the possible influences arising from experience of differently structured environments merit further consideration.

As is accepted in Chapter 4 'the size-constancy theory' has the quality of attempting to relate hitherto unexplained phenomena with well-established knowledge of the nature of other features of perceptual organisation. Irrespective of the present considerations, however, it should be pointed out that there is a variety of well-documented evidence showing that the constancy mechanism operates differentially at different stages of development. Both Brunswik (1929) and Piaget and Lambercier (1947), for example, reported that children exhibit less constancy than

adults. The implication of this is that the spatial distortions evident in illusions should be smaller in extent for children than adults. A systematic theoretical position developed in such terms as these remains to be proposed.

The general nature of the inappropriate size-depth theories was considered in Chapter 5. The argument formulated here was expressed in terms of the depth features which may be developed in spatial patterns by introducing additional further contours, indicating depth, about a straight line. This allowed a comparison to be made between the usual forms of the two components of the Müller-Lyer illusion, and two unconventional forms. As was pointed out previously, if patterns of this kind had been introduced as control features of the innumerable studies of this illusion, the argument from inappropriate computation of size in accordance with depth would have appeared questionable long before this time.

The study of illusions represents one of the strongest continuing research traditions in experimental psychology. The developmental parameters of the mechanisms responsible for their presence have not yet been delineated satisfactorily. What is required is a theory to explain the appearance of illusions in terms of the structural organisation and functional repertoire of the eye and the visual projection system. When an acceptable theory of

this kind is proposed it will explain both the present
and developmental nature of illusory spatial distortion.

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